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REPORT OF SURVEY CONDUCTED AT

**MCDONNELL DOUGLAS AEROSPACE
(MDA) (ST. LOUIS)**

ST. LOUIS, MO

MAY 1995

Best Manufacturing Practices

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**CENTER OF EXCELLENCE FOR BEST MANUFACTURING PRACTICES
College Park, Maryland**

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Foreword



This report was produced by the Best Manufacturing Practices (BMP) program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective towards this goal is simple: to identify best practices, document them, and encourage industry and government to share information about them.

The BMP program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management – all areas highlighted in the Department of Defense's 4245.7-M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource to help companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to avoid costly and time-consuming duplication of what others have already tried and learned from.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at McDonnell Douglas Aerospace (MDA) (St. Louis) conducted during the week of May 8, 1995. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from government, industry, and academia throughout the U.S. and Canada – *so the knowledge can be shared*. BMP also distributes this information through several interactive services including CD-ROMs, BMPnet, and a World Wide Web HomePage located on the Internet at <http://www.bmpcoe.org>. The actual exchange of detailed data is between companies at their discretion.

MDA (St. Louis) is a leading producer of tactical and training aircraft, military transport aircraft, strike missiles, military and commercial helicopters, space launch vehicles, space platforms, defense systems, C⁴I systems, and related services. Products include the F/A-18 (C/D and E/F), F-15, AV-8B, T-45 and Harpoon/SLAM.

MDA (St. Louis) has concentrated several efforts into the one main area of *affordability*, identified by MDA as critical not only to its own survival but to other defense-related businesses as well. This thrust is grounded in MDA's Integrated Product Definition (IPD) process, a continual effort to fold information, expertise, and value into a emerging concept as part of a fully-integrated, collaborative program that guarantees economical, high performance products. IPD is supported by "recycling" tools, processes, and lessons learned from previous programs in new programs to help control ever-increasing defense program costs. It is also supported by impressive MDA capabilities such as its high-speed machining technology.

The Best Manufacturing Practices program is committed to strengthening the U.S. industrialbase. Survey findings in reports such as this one on McDonnell Douglas Aerospace (St. Louis) expand BMP's contribution toward its goal of a stronger, more competitive, and more globally-minded American industrial program.

I encourage your participation and use of this unique resource.

A handwritten signature in cursive script, appearing to read 'Ernie Renner'.

Ernie Renner
Director, Best Manufacturing Practices

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Section 1

Report Summary

Background

McDonnell Douglas Aerospace (MDA) (St. Louis) is a leading producer of tactical and training aircraft, military transport aircraft, strike missiles, military and commercial helicopters, space launch vehicles, space platforms, defense systems, C⁴I systems, and related services. Products include the F/A-18 (C/D and E/F), F-15, AV-8B, T-45 and Harpoon/SLAM. Principal customers include the Department of Defense and foreign governments such as the Netherlands and Great Britain.

The MDA (St. Louis) complex houses MDA management and support functions as well as program management and fabrication/assembly facilities for the F/A-18, production aircraft, and the Harpoon/SLAM. Research and testing facilities, test and flight simulation laboratories, a manufacturing technology development center, and prototype airframe manufacturing facility also reside in St. Louis.

Many companies surveyed by the BMP program in the last few years have focused their energies on one or two particular areas in response to the changing shape of the defense environment. Some have concentrated on reorganization, some on producibility, some on streamlining existing capabilities and processes. McDonnell Douglas Aerospace (MDA) (St. Louis) has combined many areas under the overarching umbrella of *affordability*. This area was identified by MDA as one that is critical not only to its own survival, but to other defense-related businesses as well. To that end, the company has centered many of its practices – including the best practices in this report – on supporting affordability in its designs, manufacturing processes, and management decisions.

Although the affordability focus encompasses many initiatives, it is grounded in MDA's Process-Based Management (PBM) program and Integrated Product Definition (IPD) process. PBM is the foundation of MDA strategy and is internally defined as all enterprise-wide activities and actions to manage, maintain, and improve how MDA (St. Louis) manufactures its products. This strategy is supported by four principal goals and deployed through the focus areas of Enterprise Process Model, Enterprise Coordination, Approaches, General Improvement, Enterprise Documentation, Common Tools, and Enterprise Measures.

MDA's IPD process is a continual effort to fold information, expertise, and value into an emerging concept as part of a fully-integrated, collaborative program that guarantees economical, high performance products. This process is

pivotal to MDA's overall affordability strategy and is supported by cross-functional teams assembled from all MDA disciplines, and extends beyond concurrent engineering to synergize the right people at the right time for optimum results.

MDA (St. Louis) places particular emphasis on "recycling" tools, processes, and lessons learned from previous programs to help control ever-increasing costs in new defense programs. It has developed a database that identifies lessons learned, product specifications, MIL-SPECS, and Fleet-recommended improvements that apply to a particular product. This information provides the historical perspective as well as the means to document new lessons as they emerge. By basing existing efforts on what worked well on past programs, MDA (St. Louis) is avoiding costly mistakes while guaranteeing continued success and highly reliable products.

Affordability is supported by impressive MDA capabilities such as its high-speed machining technology. An enhanced degree of productivity can be maintained while achieving part design flexibility, weight savings, part accuracy and part quality, all of which contribute to cost. This process significantly reduces cutting forces and allows operation at ten times normal speeds and feeds for cutting aluminum parts to produce lighter weight parts with thin cross sections and smaller radii. This in turn enhances producibility and design flexibilities with lower production costs. MDA (St. Louis) has also developed a new composite curing tool manufacturing process using arc-sprayed metal. This process utilizes a low cost tooling form over which atomized molten metal is sprayed to form a thin metallic layer. The layer is removed from the original form and backed with a low-cost support structure to add strength. The result is a low cost, short lead time, high durability composite curing tool.

Affordability is not only supported by new, proven technology insertion but by also evaluating existing design criteria for items produced by MDA (St. Louis) and then making allowable changes. One case is the original design requirement of aircraft ECS ducting previously manufactured of Kevlar layups which were expensive to produce. After extensive evaluation of the ducting performance criteria, it was determined that selected ducts could be manufactured by the rotational molding process at less than half the cost.

Because affordability issues are affected by suppliers, MDA (St. Louis) expends considerable effort to develop

and enhance supplier relationships. Numerous best practices in this area were identified during the BMP survey including the Source Selection Process which MDA (St. Louis) uses to select the best value instead of low bid in procuring contractor furnished equipment, major subcontract items and support equipment, systems, and trainers. Another example is the Supplier Quality Improvement Board, a team comprised of supplier management, quality assurance, engineering, procurement, quality engineering, and program management representatives that address concerns which require management review and corrective action. The Preferred Supplier Certification program is MDA's supplier certification process for establishing long-term partnerships with suppliers. These partnerships enable MDA (St. Louis) to provide its customers with technically excellent, affordable products. This certification process focuses on the complete business process, accelerated product and process improvements, and strengthened teamwork between MDA (St. Louis) and its suppliers.

Looking for improvement in affordability issues demands benchmarking outside of the company, and MDA's benchmarking program builds on techniques used by companies such as Xerox, IBM, AT&T, Texas Instruments, and Motorola. This systematic process facilitates collecting data on superior processes, products, and services from other organizations, and focusing on those areas that impact customer satisfaction and provide competitive advantage. Specifications for enhanced performance are consequently integrated into the MDA (St. Louis) Continuous Process Improvement effort.

With the current funding environment unlikely to change in the near future, every company engaged in defense-related work is examining, streamlining, and adjusting its programs to competitively manufacture high quality, *affordable* products. McDonnell Douglas Aerospace (St. Louis) is answering this challenge by learning from past experiences, incorporating the best of its capabilities and personnel into its Integrated Product Definition process, and continually benchmarking itself against world-class competitors to provide its customers with economical, superior quality products. These activities have been integrated into MDA's product lines and are producing impressive results such as those presented in the following practices that the BMP survey team considered among the best in industry and government.

Best Practices

The BMP survey team found the following best practices at MDA (St. Louis).

Item	Page
Computational Fluid Dynamics	11
MDA's computational fluid dynamics efforts apply a collection of methods and tools to solve the governing equations of fluid dynamics.	
Control Dynamics Laboratory	11
The MDA (St. Louis) Control Dynamics Laboratory has constructed a test fixture to conduct a variety of test programs on aircraft hydraulic and flight control systems	
Crew System Design Analysis Tools	11
MDA (St. Louis) has assembled a toolbox for evaluating and improving flight crew control and escape systems. These tools use computer models to simulate, predict, and analyze the physical environment that the flight crew will see during mission scenarios.	
Development Program Configuration Control Process	12
MDA (St. Louis) has a system for documenting the configuration of individual products during the design-manufacture-assembly-test process. The system enables the change boards to document design notes, loft definition, and trade studies to provide a common definition of what the current product configuration is across the product design community.	
Engineering Documentation Storage System	13
MDA (St. Louis) uses a technology based on raster imaging technology to support the archival and retrieval of electronically-formatted mechanical drawings in its Engineering Documentation Storage System.	
F/A-18 Requirements Management	13
MDA (St. Louis) has deployed a process on the F/A-18 E/F program that utilizes a program-wide requirements database to serve as the source for all requirements documentation.	
Failure Mode, Effect, and Criticality Analysis	14
MDA (St. Louis) has developed detailed documentation and software to support a Failure Mode, Effect, and Criticality Analysis following the MIL-STD-1629A methodology. This analysis is used to evaluate the potential impact of each system failure mode on mission success, personnel and system safety, and overall performance.	

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Field Feedback	14	Technical Performance Measurement Process Improvement	19
MDA (St. Louis) uses a coordinated field feedback system to rapidly acquire information about both the product and service performance from the customer perspective.		MDA (St. Louis) successfully applies a Technical Performance Measurement process to monitor how a program is progressing with respect to the customer's technical requirements.	
Geometric Dimensioning and Tolerancing	14	Variation Simulation Analysis	19
MDA (St. Louis) has implemented geometric dimensioning and tolerancing as a management tool to provide clear definition of product tolerances and acceptable tolerance values.		MDA (St. Louis) uses variation simulation analysis to accurately predict and minimize variation in its products. This capability allows evaluation of alternative aircraft design and process concepts to facilitate the selection of optimum designs based on function, assembly processes, and cost constraints.	
Integrated Computer-Aided Software Engineering at MDA (St. Louis)	15	Weapon Separation Analysis	20
MDA (St. Louis) is applying Integrated Computer-Aided Software Engineering software development technology to enhance business information systems to re-engineer business process analysis, information analysis, system design, and software code generation.		MDA (St. Louis) developed an integrated trajectory analysis software tool to model and simulate the path of weapons as they are released from the aircraft in an effort to streamline the analysis process and to incorporate three-dimensional graphical visualization.	
Modular Six Degree of Freedom Analysis Program	16	Wind Tunnel Data System	21
The Modular Six Degree of Freedom Analysis Program is an MDA-developed, continuous system analysis tool that provides high-fidelity simulations of the complete air vehicle.		MDA (St. Louis) uses its Wind Tunnel Data System (WTDS) to gather, manage, analyze, and display wind tunnel testing results.	
Parametric Evaluation of Loft and Other Surface Data	17	Automated Ultrasonic Scanning System	21
A parametric evaluator is used by McDonnell Douglas to facilitate the exchange of loft and other surface definition data with incompatible CAD systems with no loss of definition or accuracy of the original data.		The Automated Ultrasonic Scanning System is a computer-controlled ultrasonic scanning system designed to meet industry inspection demands for highly curved, composite, and metallic parts and assemblies.	
Product Data Management	17	Computed Radiography	21
Disparate systems such as CAD, tooling, numerical control code, and a control and release system have been linked in a product data management system that provides access to a wide variety of data at MDA (St. Louis).		MDA (St. Louis) is using computed radiography for inspection applications in the non-destructive test applications. This technology has high utility, facilitates digital archiving of data, and allows magnification of associated images for easy inspection of critical features.	
Software Processes	18	Cutting Tool Development	22
MDA (St. Louis) instituted three new processes to help define and manage software development to lower the risks and make it more affordable.		MDA (St. Louis) formed the Cutting Tool Development Group to evaluate both vendor standard cutting tools and/or designs in a laboratory environment.	
System Engineering Trade Study	19		
The MDA (St. Louis) reengineered its trade study process to ensure that studies are timely and of a consistently high quality.			

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Digital Photographic Visual Aid	22	Integrated Assembly Management Process	26
The Digital Photographic Visual Aid system adds annotated photographic quality images to work instructions that are easier to interpret than line drawings.		The objective of the Integrated Assembly Management Process includes assembly knowledge acquisition, multiprocess integration re-engineering, constraint-based scheduling, and optimum resource deployment, all of which are used to lower the total cost of the assembly process.	
Drivmatics with Large Parts Handling	23	Intelligent Wire Assembly Station	26
MDA (St. Louis) helped develop machines required to meet the demands of automatically fastening large metal assemblies.		MDA (St. Louis) developed and implemented a computer-aided system for connecting wires to their respective electrical connector pin holes.	
Electronic Work Order System	23	Large Extrusion Contour Roll Forming	27
The Electronic Work Order System, developed by MDA (St. Louis) as an Air Force MANTECH project, integrates manual and automatic shop floor processes with computer-integrated manufacturing planning, scheduling, and control.		MDA (St. Louis) installed a precision contour roll machine system capable of rolling and forming complex shapes in long extrusions up to 40 feet long. This system replaces the manual operation using complex stretch dies which was dependent on the skill and experience of the mechanic.	
Environmental Improvement Initiatives	24	Low Cost Composite Tooling	27
MDA (St. Louis) established the Environmental Assurance division to perform technical and business analyses for selecting the most cost-effective and low-risk compliance methods to meet environmental directives projected to take effect during the next seven years.		MDA (St. Louis) developed a new composite curing tool manufacturing process using arc-sprayed metal.	
Finite Element Model Weight Estimation	24	Low Rate Expandable Tooling	28
The Finite Element Model Weight Estimation System is a set of management software tools at MDA (St. Louis) that provides information early in the design process to allocate resources to manufacture low cost, lightweight airframes.		The Low Rate Expandable Tooling assembly concept reduces the total number of tools required to assemble a major aircraft assembly at a low production rate.	
Fire Services 24-Hour Shift	25	MODIG Extrusion Router/Driller	28
In an effort to control rising costs, reduce the need for overtime and provide improved services, MDA (St. Louis) Fire Services has transitioned from a traditional eight-hour workshift to a 24-hour shift, patterned on the surrounding public fire service agencies.		MDA (St. Louis) invested in state-of-the-art machine tools to automatically perform complex, labor-intensive machining operations on aluminum extrusion material.	
High Pressure Guerin Forming Process of Aluminum Sheet Metal	25	Paperless Material Review/Corrective Action System	28
McDonnell Douglas Aerospace applies guerin forming, or rubber pad forming, to improve the quality and producibility of sheet metal parts.		MDA (St. Louis) is installing an automatic material review and corrective action system to address a need for a non-conformance graphics capability.	
High Speed Machining System	26	Preferred Supplier Certification Process	29
MDA (St. Louis) maintains high speed machining as a critical technology which addresses part design flexibility, weight savings, part accuracy, and part quality.		MDA (St. Louis) maintains a supplier certification process to establish long-term partnerships with suppliers as part of its efforts to satisfy customers with top quality, technically excellent, affordable products that are delivered on time.	

Item	Page	Item	Page
Project Deployment: Technology Transition to Production	30	of quality, and to address concerns which require management review and corrective action.	
Because current and future environmental regulations have an impact on manufacturing, MDA (St. Louis) devised a way to change production processes to comply with the regulations with the least amount of risk to the production programs.		Theodolite Coordinate Measurement Systems	33
Rotational Molding Process	31	MDA (St. Louis) has been using theodolite coordinate measurement systems since the mid-1980s as replacements for optical transits and tooling bars, reducing manufacturing application and inspection times.	
MDA (St. Louis) has adopted and adapted a manufacturing process known as rotational molding to eliminate the need to fabricate a tool each time a part is built.		Variability Reduction	34
Small/Small Disadvantaged Business Subcontracting Program	31	MDA (St. Louis) has addressed the problem of understanding and designing for variation in component parts by using Integrated Product Definition data sheets which query the way a part is dimensioned and toleranced in relation to its functional use in a component.	
MDA (St. Louis) is aggressively improving its Small and Small Disadvantaged Business Subcontracting Program. Improvements include expanded support of the Historical Black College and Universities and the Minority Institutions program, and a Mentor-Protégé program.		Benchmarking Process	34
Superplastic Forming/Diffusion Bonding	31	The benchmarking process at MDA (St. Louis) is a systematic and continuous measurement process for collecting benchmarks on superior processes, products, and services from other organizations.	
MDA (St. Louis) has successfully developed and used titanium superplastic forming technology on fighter/attack aircraft.		CALS/CITIS	35
Supplier Advisory Council	32	MDA (St. Louis) combined the Continuous Acquisition and Life-cycle Support goal and Contractor Integrated Technical Information Service capability into a single environment which supports the effective execution of Integrated Product Development.	
The Supplier Advisory Council provides a leadership focus to issues that improve the affordability and effectiveness of MDA (St. Louis) suppliers, and provides supplier insight to assist MDA in enhancing the competitive posture of its products.		Enterprise Process Model - the Eight Key Processes	36
Supplier Conferences	32	MDA (St. Louis) uses a Model Structure to ensure complete and systematic coverage in its process-based management effort, and the highest level is divided into eight key processes.	
A three-tiered supplier conference program helps MDA (St. Louis) institute an infrastructure of support as it moves toward full partnership with its suppliers.		Foreman Development Process	37
Supplier Performance Evaluation and Rating System	32	In mid-1993, MDA (St. Louis) developed a program to train new foremen and improve the performance of current foremen, as a structured approach for promoting bargaining unit employees to foreman positions did not exist, and newly-promoted foremen were given little substantial supervisory training.	
The Supplier Performance Evaluation and Rating System uses three metrics to evaluate and rate the suppliers – quality, on time delivery, and a factor MDA (St. Louis) calls responsiveness.		Hornet Quality Award	37
Supplier Quality Improvement Board	33	The Hornet Quality Award was established as the preeminent form of team recognition for F/A-18 aircraft program to encourage the teams to produce quality products on time, and to recognize teams instead of individuals or managers.	
The Supplier Quality Improvement Board is a multidiscipline management team established by MDA (St. Louis) to review suppliers whose performance has declined below an acceptable level			

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The Hornet Wire	38	include all product analyses pertinent to supporting the customer and products in the field.	
The <i>Hornet Wire</i> is a daily newsletter for the F/A-18 program that is distributed through electronic mail to rapidly distribute new information and provide the means for open communication.		Logistics Support Analysis Record	42
Inside Compensation Newsletter	38	The relational design of the Logistics Support Analysis Record data at MDA (St. Louis) was developed to facilitate integration and to encourage the use of ad-hoc queries for accessing different data files.	
MDA (St. Louis) has introduced an Inside Compensation Newsletter to inform employees of policy and/or philosophy changes in the merit review process.		People Strategic Plan - 1995	43
Integrated Management Information and Control System	38	The People Strategic Plan integrates all human resources inputs and implementation plans throughout the MDA enterprise to establish a coordinated, non-duplicative employee program plan.	
The Integrated Management Information and Control System at MDA (St. Louis) is an electronic bulletin board which displays a spectrum of program health indicators such as cost, schedule, and technical risk.		Performance Cost and Schedule Process	43
Integrated Product Development Certification	39	MDA (St. Louis) developed a process-based management approach to cost and schedule control systems and merged two division manuals on cost/schedule control system criteria into one Process Management Guide.	
The Integrated Product Development Certification process is a tool for providing a structured methodology to assess and improve the current state of Integrated Product Development implementation.		Presenteeism Program	43
Integrated Product Definition Process	40	A program was implemented at MDA (St. Louis) in 1984 as an incentive to encourage and recognize those employees who achieve perfect attendance.	
MDA (St. Louis) created its Integrated Product Definition program in 1992 to identify all required activities and personnel required to deliver a product to internal customers and suppliers.		Problem Identification, Escalation, and Resolution Process	44
Integrated Product Definition Quality Measures	40	The Problem Identification, Escalation, and Resolution Process helps MDA (St. Louis) manage the life-cycle of problems that occur within a product team's area of responsibility, authority, and accountability.	
The use of Integrated Product Definition Quality Measures at MDA (St. Louis) provides on-line management tools for managers and team members to monitor performance to goals for Integrated Product Definition critical processes and tasks.		Process Assessment Guide	44
Integrated Training Plan	41	The Process Assessment Guide was developed by MDA (St. Louis) to help users assess, evaluate, and analyze process maturity.	
MDA (St. Louis) has a viable, well-documented process that meets the training requirements of the corporate organization and its individuals, and is balanced with corporate affordability considerations.		Retrofit Configuration System	44
Logistics Support Analysis	41	The Retrofit Configuration System at MDA (St. Louis) incorporates digital data for aircraft life cycle support and provides digital information that supports product functionality and configuration control.	
Logistics Support Analysis processes within MDA (St. Louis) have been systematically enhanced to		Strategy-to-Technology Process	45
		MDA (St. Louis) developed a Strategy-to-Technology Planning System to aid in program requirements definition. It was designed by modifying	

Item	Page	Item	Page
the Quality Function Deployment methodology to meet the specific needs for this system.		Avionics Engineering Process Handbook	49
Supplier Best Practices	46	MDA (St. Louis) developed an Avionics Engineering Process to include work to be done, in what order, and by what work groups. It is also a reference document that details products, internal and external review requirements, and the necessary coordination among work groups.	
Teams from MDA (St. Louis) perform Business Process Assessments as part of MDA's Preferred Supplier Certification process, and collect information on processes and techniques which are efficient and effective, some of which may have application at MDA or be used to improve the overall supplier base.		Baseline Comparison System	50
Supplier Management Proficiency Program	46	The Baseline Comparison System is a set of current operational systems/equipment, or a composite set of current operational systems/equipment at MDA (St. Louis), which most closely represents the design, operational, and support characteristics of a proposed system or equipment under development.	
The Supplier Management Proficiency Program is a training program to ensure the disciplined and consistent application of proven supplier management techniques.		Design for Manufacturing and Assembly	51
Total Quality Management System and Process-Based Management	46	MDA (St. Louis) developed the Design for Manufacturing Assembly process to reduce inventory and work-in-progress which together represent 51% of MDA's total assets.	
MDA's corporate-wide total quality management system emphasizes process over product, a philosophy that began in 1987 with internal self-assessments using the Malcolm Baldrige criteria.		Electronic Development Process	52
Information		MDA (St. Louis) uses an Electronic Development Process to divide three-dimensional electronic mock-ups of aircraft into discrete zones or volumes. This program has produced positive results in post-release change activity.	
The BMP survey team identified the following information items at MDA (St. Louis).		Engineering/Manufacturing Tracking System	52
Item	Page	The Engineering/Manufacturing Tracking System provides MDA (St. Louis) with the capability to develop unique, multidivisional schedules for each activity from the release of an engineering drawing through loading the part onto the jig fixture.	
Advanced Design for Quality Avionics Systems/Design for Quality Aerospace Systems	49	Feature-Based Machining	52
The Advanced Design for Quality Avionics Systems and Design for Quality Aerospace Systems processes provide discipline and repeatability to the product development process from the development/acquisition phases through operations and support.		MDA (St. Louis) is developing software for Unigraphics that explores the impact of feature-based machining on processes and business cases.	
Automated Mass Properties System	49	Lessons Learned/Supportability Design Baseline	53
The Automated Mass Properties System is an interactive system that weight engineers can use to calculate surface areas and volumes rapidly, calculate area properties, calculate volume properties, manipulate the calculated properties, store properties and geometry definitions, and transmit properties to input files for database input.		MDA (St. Louis) developed a lessons-learned database system in response to a Navy requirement that all lessons learned must be reviewed and applied to new products. The system contains lessons learned from MDA, the Navy, and Air Force.	

Item	Page	Item	Page
Programming Coordinate Measuring Machines	53	powerful pulse of high intensity light to destroy the molecular structure of surface coatings while a low pressure stream of dry ice particles cools the surface and sweeps away the ablated coating residue.	
MDA (St. Louis) uses an off-line programming procedure to create inspection data points for checking machined parts using a ZEISS Coordinate Measuring Machine.			
Ready-to-Fabricate Process	53	Ion Vapor Deposition	56
MDA's Ready-to-Fabricate Process is an organized and integrated development process for structural equipment that begins with the description of conceptual layouts.		MDA's (St. Louis) ion vapor deposition process deposits a uniform, dense coating of pure aluminum on steel, titanium, and aluminum alloy parts and provides outstanding corrosion protection. It eliminates many of the associated environmental problems of vacuum deposited cadmium, electroplated cadmium, and diffused nickel-cadmium.	
Unigraphics	54	Large Order Assembly Planning System	56
MDA (St. Louis) extensively uses Unigraphics as its standard CAD/CAM system for creating build-to packages, assemble-to packages, digital mock-up models, tool design, and the manufacture of tools and parts.		MDA (St. Louis) has developed a computerized planning process—or Large Order Assembly Planning System—to enhance the assembly of large order items. It uses a relational database on an IBM mainframe computer to provide step-by-step assembly instructions to shop personnel.	
Wind Tunnel Measurement Techniques	54	Laser Guided Ply Locating System	56
The need for improved quality and greater efficiency in wind tunnel test measurement techniques provided the impetus for MDA (St. Louis) to develop three new methods of testing		MDA (St. Louis) has installed a Laser Guided Ply Locating system by General Scanning for composite part manufacturing. The system uses lasers to project the outline of the individual plies and cut-outs directly onto a hard tooling locator tool.	
Advanced Trim and Drill Cell – Composites	54	Laser Tracking System	57
This large, flexible Trim System that combines an Abrasive Water Jet System and High Speed Spindle Technology system will increase trim edge quality, reduce manpower, and reduce perishable tool usage while providing a capability for large composite and complex contour parts.		MDA (St. Louis) purchased a three-dimensional laser tracking system from Leica in 1994 as a state-of-the-art portable inspection system that can be used in various locations throughout the plant.	
Airbag Shimming on the F/A-18 E/F Wing	55	Machining Center Feature-Based Process Coding Methodology	57
The F/A-18 E/F requires 100% liquid shimming between composite and mating structures. MDA (St. Louis) applies an airbag shimming method which uses a large, low pressure, pneumatic tool to apply constant, uniform pressure over large, irregularly shaped surfaces while the liquid shim material cures.		The Machining Center Feature-Based Process Coding Methodology enhances the group technology baseline efforts to include process information for feedback to designers to improve detailed part design.	
Fiber Placement	55	Metronor Photogrammetry	57
A fiber placement process allows MDA (St. Louis) to fabricate large and complex parts that are difficult to manufacture by conventional methods.		MDA (St. Louis) is piloting the implementation of a Metronor Photogrammetry System, a video-camera based, computer-coordinated measurement tool that provides three-dimensional x, y, and z points.	
FLASHJET™ Coating Removal Process	55		
MDA (St. Louis) obtained a patent for an automated robotic technology identified as the FLASHJET™ Paint stripping process that uses a			

Item	Page	Item	Page
Paperless Assembly Data Delivery System	58	Ethics Refresher Process	60
The Paperless Assembly Data Delivery System provides an efficient, integrated, electronic system for delivering, retrieving, processing, and storing assembly build data and work instructions.		MDA (St. Louis) conducts a continuing ethics awareness program for all employees to support the belief that adherence to ethical principles of behavior produces high quality products and loyal employees, customers, suppliers, and investors.	
Predictive/Proactive Maintenance Management	58	Field Visits/Site Surveys	61
MDA (St. Louis) addressed the need for effective maintenance scheduling and machine monitoring that is critical to sustaining its high quality and complex machining capability.		MDA (St. Louis) conducts field visits/site surveys for early assessment of customer locations and facilities for the placement of weapon systems.	
Production Control Super Cribs	58	Field Service Engineer's Manual	61
MDA (St. Louis) installed a Noran bar coding system utilizing radio frequency data transmission within its warehouse facility to eliminate manual recordkeeping methods and inconsistent material distribution techniques.		The Field Service Engineer's Manual provides the working level detail necessary for the Field Service Engineer's successful conduct of daily support operations throughout the world and addresses support for the customer in the field as well as support for the MDA corporation.	
Source Selection Process	59	Instructional Design Consulting Manual	61
MDA (St. Louis) developed a source selection manual that addresses the best value instead of low bid in procuring contractor furnished equipment, major subcontract items and support equipment, systems, and trainers.		Using an industry standard process, internal instructional design consultants at MDA (St. Louis) help customers generate specific training programs and materials to be used with their work groups. An Instructional Design Training Guide has been published that describes the consulting process used to assist customers in developing training programs.	
Supplier Base Management Process	59	Methodology for Process Improvement Monitoring	62
The Supplier Base Management System at MDA (St. Louis) helps reduce the total number of suppliers without affecting the quality of products or services received and is designed to eliminate poorly performing suppliers while encouraging others to participate in the Preferred Supplier Certification process.		Human Resources developed a quick and manageable methodology to review and monitor process improvements within its organization.	
CAD/CAM Training	59	New Business Acquisition Process	62
Retraining users on the Unigraphics Version 10 will be accomplished using the Computer-Assisted Self Teach On-Line Library training program instead of the traditional method of instructor-led classes.		MDA (St. Louis) combined best practices from MDC, then benchmarked against many leading companies, and secured the services of an outside consultant to develop a carefully considered and structured approach toward acquiring new business.	
The Creative Edge	60	On-Line Spares Acquisition	62
MDA (St. Louis) has created a pilot program to encourage and recognize employee involvement as part of the continuous improvement process.		MDA (St. Louis) has developed an on-line spare parts requisitioning capability that enables customers to access and order spare parts automatically through the use of Electronic Data Interchange.	
Enterprise Quality Improvement Board	60		
The Enterprise Quality Improvement Board at MDA (St. Louis) ensures consistency of enterprise quality improvements by identifying initiatives and monitoring them through completion.			

Item	Page	<i>Activity Point of Contact</i>
Recognition Programs Structure	63	For more information on any topic in this report, please contact:
MDA (St. Louis) instituted a structured awards program to enhance morale and productivity in the work force.		
Retrofit Kit Proofing Support	63	Mr. Rob Herhold McDonnell Douglas Aerospace (St. Louis) 325 J.S. McDonnell Boulevard Mail Code 3062333 St. Louis, MO 63042 (314) 232-0879 Fax: (314) 233-0252
MDA (St. Louis) has instituted retrofit proofing to comply with an Air Force requirement to ensure that component parts, drawings, personnel skills, and procedures are available to complete the retrofit.		

Section 2

Best Practices

Design/Test

Computational Fluid Dynamics

MDA (St. Louis) applies a collection of methods and tools in Computational Fluid Dynamics (CFD) to solve the governing equations of fluid dynamics. The CFD group is responsible for providing the predictions of fluid or air flow based on complete mathematical solutions.

The CFD group is comprised of personnel with quantitative knowledge capable of understanding physical fluid dynamics, theoretical governing equations, mathematical models, numerical solutions, data visualization tools, and advanced computers used for computing the infrastructure. CFD provides an understanding of key fluid dynamic interactions with a three-dimensional description of flow. This data is used to help focus the design process and provide wind tunnel-to-flight corrections. The group can provide quantitative data at cruise conditions which is comparable to the wind tunnel. They are also able to provide unsteady flow predictions in simple cases for inlet dynamics, jet acoustics and dynamics, and cavity flowfields.

Presently, the CFD group uses Parallel Workstations, the NASA Cray C90, and Intel Paragon computers to do the extensive calculations required to construct a mathematical model of the airflow around aircraft and to be able to predict the influence of design changes. NASA supercomputers and a Heterogeneous Parallel System are projected for future use by the CFD group.

MDA (St. Louis) used a CFD analysis to provide corrections to the aero performance database. The CFD prediction for the same program was delivered on a faster schedule than the wind tunnel and at 6% of the cost. The quality of the prediction was verified in separate reviews by MDA (St. Louis) and the customer. Another program was able to use CFD to guide the aero optimization and loads database. The CFD group also provided performance and load increments for subsequent configuration changes to the same program.

The CFD group plans to acquire a prediction capability with accuracy equivalent to the wind tunnel for steady state flows. Predictions of unsteady flow in the area of acoustics, structural dynamics, multiple bodies, and aircraft dynamics will be improved.

Control Dynamics Laboratory

The MDA (St. Louis) Control Dynamics Laboratory has constructed a test fixture to conduct a variety of test programs

on aircraft hydraulic and flight control systems. Known as the "Iron Bird," the steel structure is used to conduct test of actual flight worthy hydraulic systems and flight control actuators under controlled conditions in response to inputs from flight control computers installed on test benches. This system is used for initial component development, system development, and test. It is also used to solve problems which develop in mature systems.

A unique feature of the F-15 Iron Bird is that it is presently configured to support both F-15E and Short Take-Off and Landing (STOL)/Maneuvering Technology Demonstration Programs. A series of manual valves are used to connect system unique components to the hydraulic system. Flight controls, flight control computers, and data acquisition systems are located in adjacent rooms. The ease of transition permits different configurations to be run on successive shifts.

Crew System Design Analysis Tools

MDA (St. Louis) has assembled a toolbox with both internally-developed and third party software for evaluating and improving flight crew control and escape systems. These tools use computer models to simulate, predict, and analyze the physical environment that the flight crew will see during mission scenarios. This includes parameters such as reach distances for controls, vision capabilities, crew workload, heat in the cockpit, and ejection thrust. In addition to software tools, MDA (St. Louis) utilizes many hardware tools to collect data such as lighting, sound, torque, and force exertions for input to the analysis tools. Crew station concepts and improvement ideas can be evaluated using a rapidly reconfigurable cockpit.

MDA's (St. Louis) software tools accomplish the following tasks:

- rapid prototyping for cockpit displays with built-in flight simulation,
- human factors analysis of human body fit and function,
- analysis of the visual impact of components in a pilot's visual path,
- modeling and analysis of human-machine integration requirements,
- simulation and analysis of the thermal behavior of the human body,
- assessment of the performance of the ejection system, and
- simulation of combat maneuver G forces and resultant human responses.

MDA's (St. Louis) hardware tools measure luminance levels and chromaticity; perform spectral analysis; measure and define force requirements; measure sound levels, visual contrast sensitivity, and human body dimensions; facilitate design tool use in a lighting room, acoustic chamber or experiment room; provide a mock-up crew station for rapid testing and evaluation; and provide mock-up lighting for experiments.

These tools are continuously evaluated for upgrade or replacement when improved capabilities are needed, with an annual budget allocated to procure high priority upgrades. Recently, a survey was conducted to investigate upgrade requirements in an effort to ensure that employees have the tools they need to effectively do their jobs.

Development Program Configuration Control Process

MDA (St. Louis) uses a process for documenting the product configuration during the design, manufacture, assembly, and test process. The system consists of two elements – a monthly configuration update matrix and a document that contains a top-level description of the aircraft.

The monthly configuration update matrix reflects the change board decisions that affect the aircraft configuration. The configuration matrices allow MDA (St. Louis) to quickly identify all aspects of the design configuration that could potentially be affected by any change. This enables MDA (St. Louis) change boards to document design notes, loft definition, and trade studies to provide a common definition of the current product configuration across the product design community. It also provides a single configuration baseline for the monthly Technical Performance Measurement process which assesses design maturity/requirement conformance.

The Configuration Description document is periodically reissued to reflect the cumulative impact of the change board decisions on the actual design. The monthly update matrices defined the changes that impact the configuration definition. This documentation contains text and graphics portraying the air vehicle, airframe, subsystems, avionics, armament, new technology, and flight test installations. It is updated to support key program milestones, ranging from Critical Design Review to Low Rate Initial Production (Figure 2-1). This process can track multiple design baselines from actual through planned configurations.

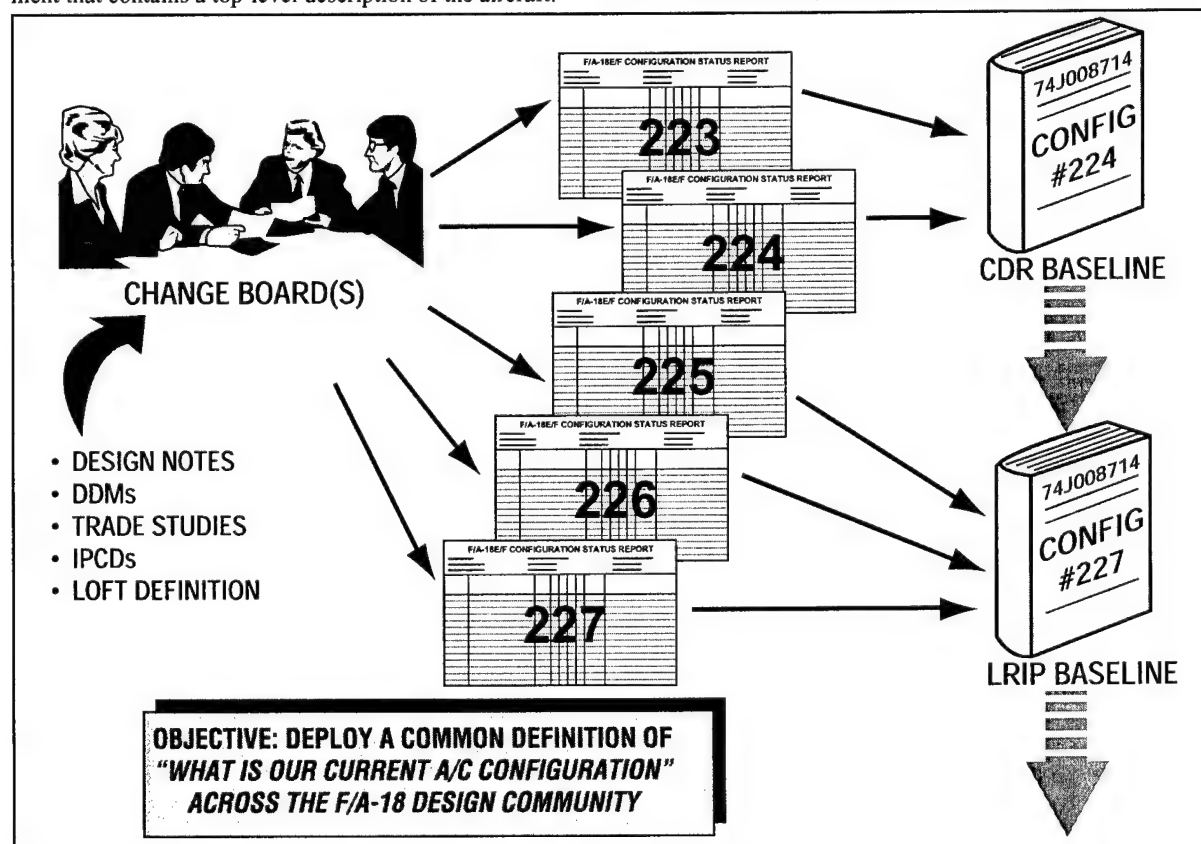


Figure 2-1. F/A-18E/F Configuration Description

Engineering Documentation Storage System

MDA (St. Louis) uses a state-of-the-art drawing storage technology in its Engineering Documentation Storage System (EDSS). This technology is based on raster imaging technology and supports the archival and retrieval of electronically-formatted mechanical drawings. Once the drawing is released, turnaround for drawing availability is no more than 1 or 2 days, depending on the medium in which the drawing was submitted. This rate represents a substantial time savings over the previous 30 days.

The EDSS provides electronic media for mechanical drawings by scanning the originals and converting them into an electronic format with high data integrity. These electronic drawings support integrated product design and efficient data storage techniques. EDSS alleviates the necessity for paper data centers and aperture cards, providing a single source for data integrity and accountability with remote access to the optical disk repository. Use of the EDSS has contributed to a reduction in print costs, scrap, rework, and repair.

The availability of high integrity electronic drawings has accelerated related integrated product and process design efforts in-house such as electronic commerce with suppliers and the PADDS shop floor control program. Presently, all drawings are scheduled for electronic entry into the system with legacy requirements being updated as needed. EDSS operates concurrently with the existing print crib system, but MDA (St. Louis) has plans for closing the print cribs as

the proliferation of the EDSS continues. Over 1200 devices are connected to the on-line electronic drawing system, and remote site installation for digital delivery of data per Continuous Acquisition and Life-cycle Support (CALS), missiles programs, and electronic commerce continues. Current estimated savings from implementing EDSS is over \$4.5M, attributed to the reduction of scrap and rework, blueprint and reproduction cost and, consolidation of existing print cribs.

F/A-18 Requirements Management

MDA (St. Louis) applies a process in the F/A-18 E/F program (Figure 2-2) that uses a program-wide requirements database to serve as the source for all requirements documentation. The process is iterative and consists of four elements – identification, allocation, implementation, and verification. The primary management tools are a series of matrices that define and document allocations of requirements to design elements, downward flow of requirements to lower levels of detail, and the methodology used to verify proper implementation of each contract requirement.

The process involves three key types of matrices. The Requirements Allocation Matrix is used to manage the allocation and implementation of each requirement. The Derived Requirements Allocation Matrix follows from the Requirements Allocation Matrix and is used to manage MDA (St. Louis) internal requirements. The Requirements Verification Matrix manages the association of requirement-to-verification methodology and program milestones.

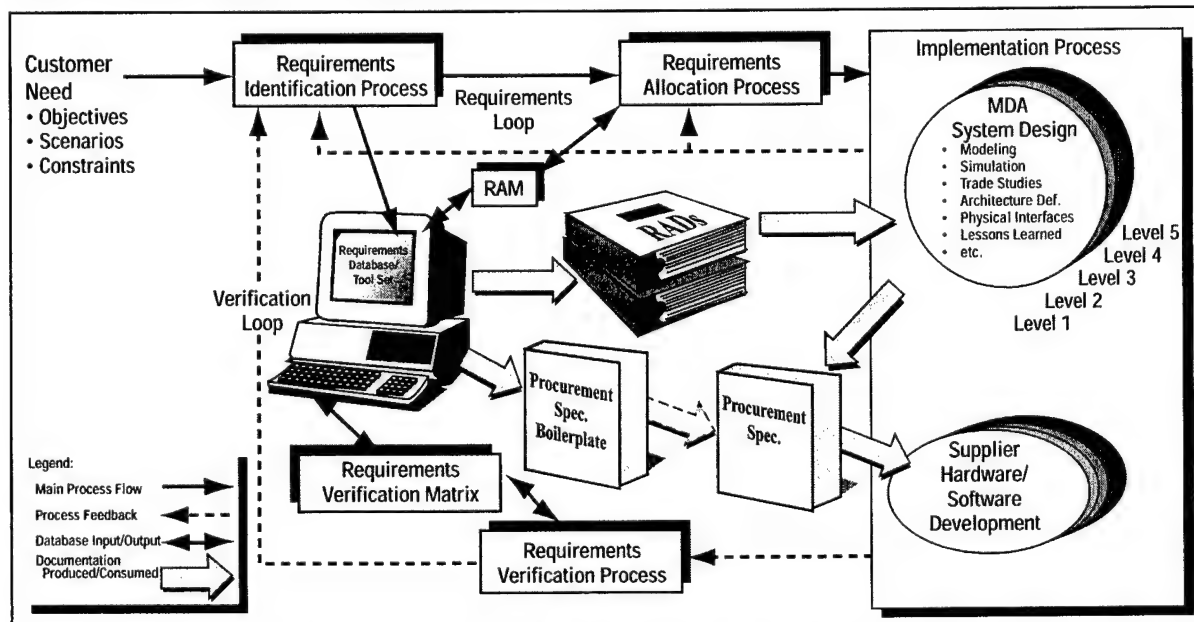


Figure 2-2. MDA Requirements Management Process

These matrices are used to produce a MIL-STD-490 format Requirements Allocation Document and support the completion of the Functional Configuration Audit.

As the F/A-18 E/F program moves into production, this requirements management process provides electronic requirement-based analysis of potential changes, affording management with better insight into change impact prior to implementation. The requirements database supports the assessment of how well a design satisfies a requirement, and verification of the satisfaction of a requirement. The process, database, and management tools are used to support Integrated Product Development and can be accessed by MDA (St. Louis), Northrop NGC, and selected MDA subcontractors.

Failure Mode, Effect, and Criticality Analysis

MDA (St. Louis) has developed detailed documentation and software to support Failure Mode, Effect, and Criticality Analysis (FMECA) patterned on the MIL-STD-1629A methodology. FMECA is used to evaluate the potential impact of each system failure mode on mission success, personnel and system safety, and performance.

FMECAs consist of two distinct steps. First, a Failure Mode and Effects Analysis (FMEA) is conducted to identify all failure modes within a system design. Secondly, a Criticality Analysis is conducted to rank each failure mode identified in FMEA according to the combined influence of severity classification and its probability of occurrence. The results of the Criticality Analysis determine the requirement for design control of catastrophic and critical failure modes.

Previously, FMECA was conducted and documented manually through a tedious, labor-intensive process. The need to standardize and computerize this process was driven by the implementation of integrated product teams. The use of these teams required that the data to perform FMECAs had to come from several personnel with varying backgrounds and varying geographic locations. Additionally, much of the data needed to initiate an FMECA had to come from vendors.

To solve these problems, MDA (St. Louis) developed a VAX-based software package called Automation Software for Supportability Engineering Tasks. This system standardized data input, analysis, output reports, and documentation of the analysis. Further, standardizing and planning the FMECA process simplified the management of supplier data. Engineers could then know what information to ask for, what format was required, and what the associated timeframes were.

Automating this system means that now a typical FMECA can be conducted in one-tenth the time required manually.

The new system increases efficiency by allowing the re-use of data for follow-on FMECAs for similar systems or for similar components within systems. The process also benefits logistical planning because the expected failure modes and rates are determined during FMECA.

Field Feedback

MDA (St. Louis) uses a coordinated field feedback system to rapidly acquire information about the product and service performance from the customer's perspective. Feedback from field sites is collected through the Problem Identification, Escalation and Resolution (PIER) process, used by customers directly or through field service engineers.

The PIER process helps identify customer dissatisfaction and facilitates resolution. Field service engineers use a Field Service Reporting Information System to collect and submit technical and product-related problems. This data is linked to the Quality Improvement Management system where assessments are performed to determine root cause and develop corrective actions. The Check-Six system, sponsored by the president of MDA (St. Louis), is an informal system designed to provide customers easy access to MDA (St. Louis) management. Check-Six forms are distributed and coordinated through field service engineers and business development personnel and are tracked, managed, and responded to by senior management.

The field feedback systems have been beneficial to MDA (St. Louis) in helping the company maintain customer satisfaction with its products and services. An independent customer satisfaction survey is being conducted to identify the customer's needs and desires to ensure that they are being met by MDA (St. Louis).

Geometric Dimensioning and Tolerancing

MDA (St. Louis) has implemented Geometric Dimensioning and Tolerancing (GD&T) as a management tool to provide clear definition of product tolerances and maximize the use of acceptable tolerance values. When preparing to implement GD&T, the company established three goals:

1. Develop GD&T practices in the Integrated Product Development teams to optimize tolerances and clearly define the allowable variation of product definition.
2. Develop manufacturing and inspection capabilities to achieve full compliance with GD&T-specified requirements at the lowest possible cost.
3. Integrate GD&T application and interpretation with the Integrated Product Development teams and manufacturing processes through dimensional management.

In support of successfully implementing the GD&T program, MDA (St. Louis) created extensive training courses, developed internal consultants and mentors, formed the MDA (St. Louis) GD&T Committee, and provided a member to serve on national and international standards development committees. Basic and advanced training courses were developed, and over 1800 employees have received the training. The curriculum and training materials used were developed by MDA (St. Louis) and includes textbooks, student manuals, instructors' manuals, and the models to demonstrate the instructions.

To help consistently interpret geometric dimensioning and tolerancing information, MDA (St. Louis) also assembled internal consultants and mentors and published this list for each building. MDA (St. Louis) also formed a GD&T committee to identify these internal consultants and mentors. This committee is comprised of people from different disciplines who review requests for clarification of the ANSI Y14.5M Standard and issue bulletins which provide information and policy guidelines.

MDA (St. Louis) asserts that consistent interpretation of the requirements by manufacturing and inspection will provide cost benefits. Using GD&T in the fabrication of a bulkhead assembly led to loading the bulkhead into the assembly fixture in eight hours as opposed to the previously required 3 days. With the use of a fully functional tolerance zone, there is increased tolerance without reduced quality. On one project, the use of shims was eliminated when attaching a leading edge extension assembly, which led to a savings in time and cost.

MDA (St. Louis) has received significant results through its GD&T efforts and is continually updating the training, internal expertise, and materials to ensure that skill levels are maintained.

Integrated Computer-Aided Software Engineering at MDA (St. Louis)

Integrated Computer-Aided Software Engineering (I-CASE) activities provide an example of how MDA (St. Louis) management is actively addressing critical affordability issues. This effort is dedicated to making information systems at MDA (St. Louis) more cost effective. The program is applying I-CASE software development technology to enhance business information systems to re-engineer business process analysis, information analysis, system design, and software code generation.

In 1993, MDA (St. Louis) examined the prospect of re-engineering processes in its internal information systems departments to improve affordability of information systems, reduce cycle time, enable skill shift, and reorient the development process within the information systems orga-

nization. Implementation began in 1994 and was greatly facilitated by the use of Information Engineering Facility (IEF) software acquired from Texas Instruments Inc. The IEF application provided excellent results in the engineering domain, and MDA (St. Louis) believed the same information methodology could be applied to the business domain.

MDA (St. Louis) needed to initiate a skill shift for software developers away from low level software coding and syntactic corrections toward understanding the target business process application. The IEF minimizes software coding by providing a graphical capability for the user to model the target process, and generates the software code for that process model without errors. The graphical interface provides the user with a friendly environment in which to develop the business process model and required data. In the background, IEF maintains the standard methodology and software schema for software process model compatibility.

IEF runs in a client-server environment, driven by a host encyclopedia that provides a common repository for reusable process models and data (Figure 2-3). The encyclopedia contains MDA corporate information used in all process models, thereby maintaining consistent data. This I-CASE effort provides robust capabilities for eliminating syntax error. Logical specifications are independent of the

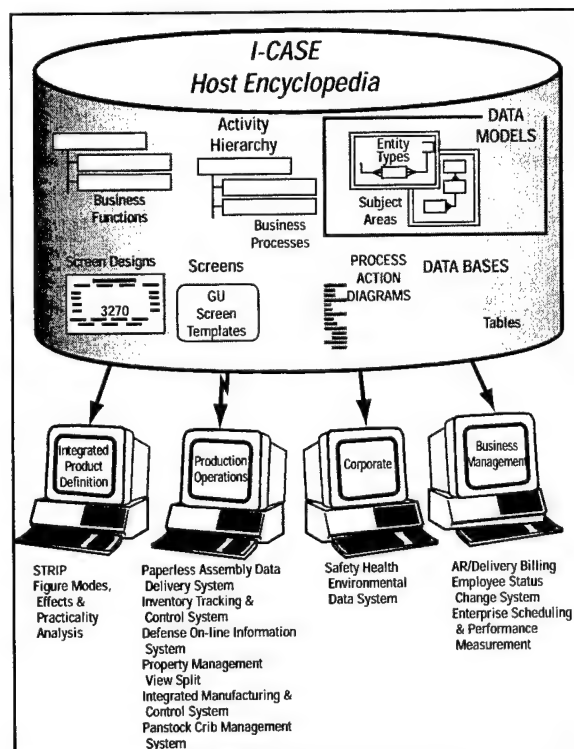


Figure 2-3. MDA Common Repository

target technology such as the user interface system and programming languages.

MDA (St. Louis) is currently quantifying the I-CASE benefits using metrics such as functional points. Some preliminary returns have shown that at start-up, the return on net assets was predicted to be approximately -160% due to the initial investment. Actually, MDA experienced a 33% return on net assets in the first year of implementation. Additionally, MDA has attained an average productivity increase of 109% for projects completed. The Paperless Assembly Data Delivery System (PADDS) program is one example of I-CASE use, where the PADDS development team, consisting of management and shop floor users, did not have to learn the target technology to implement the system, thereby allowing acceleration of the start-up schedule.

Modular Six Degree of Freedom Analysis Program

The Modular Six Degree of Freedom (MODSDF) Analysis Program is an MDA-developed, continuous sys-

tem analysis tool that provides high-fidelity simulations of the complete air vehicle. This highly modular software program is designed to be an integrated multidiscipline resource which uses a shared database. MODSDF provides engineers with efficient and validated models and methods which can be applied uniformly across MDA (St. Louis) product lines to a wide variety of engineering tasks. It replaces a large number of single-purpose simulation programs and databases.

MODSDF capabilities include single and multirate model calling frequencies, analog and digital control system simulations, flat or rotating spherical earth equations of motion, MIL-SPEC turbulence and aircraft carrier airwake models, and open-loop analysis of control systems. Among other applications, MODSDF is used to analyze full six-degree-of-freedom aircraft carrier suitability and performance characteristics, flight control design evaluation, verification of manned simulator models, weapon separation characteristics and flight test program plans and clearances (Figure 2-4), and reproduction of flight anomalies for incident and accident investigation.

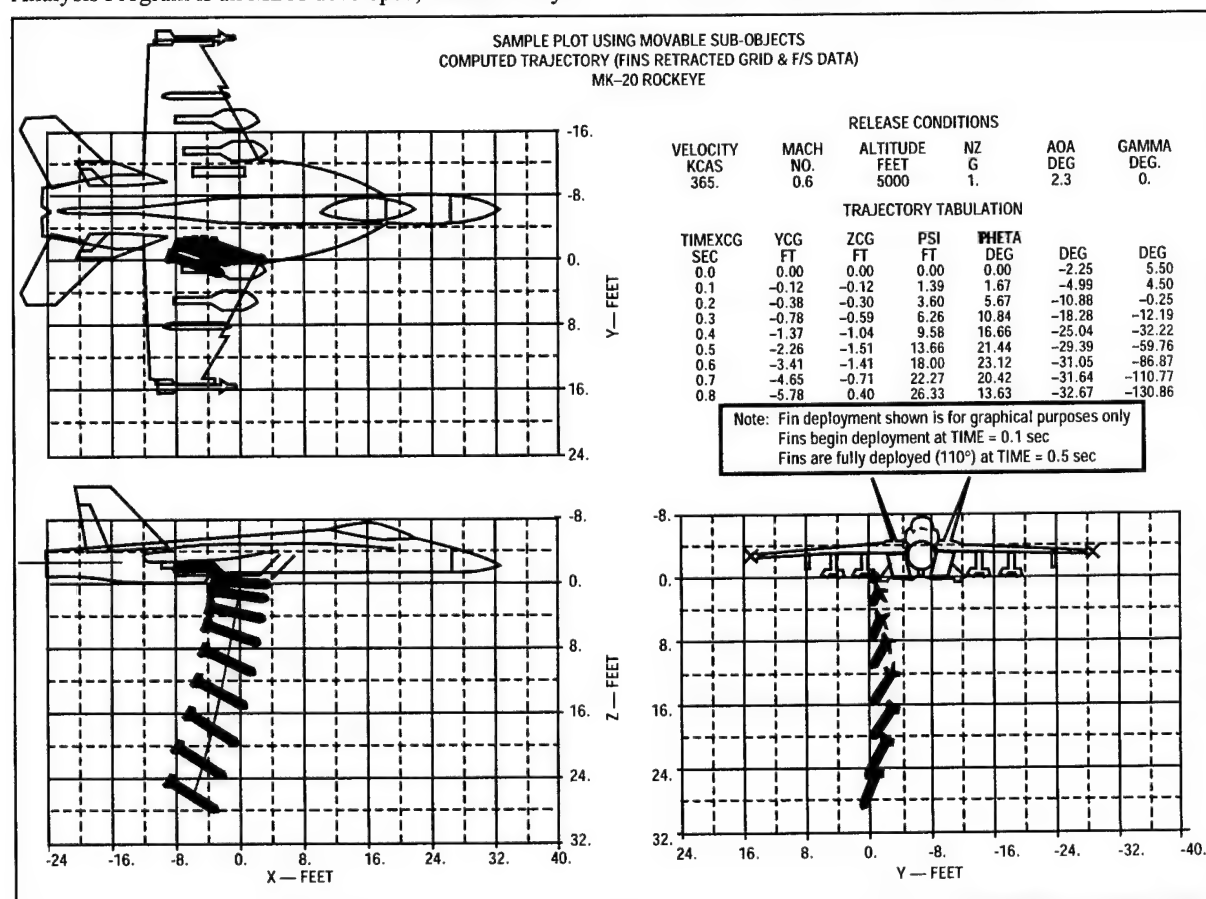


Figure 2-4. Sample MODSDF Separation

When used to analyze design and fatigue loads on the F/A-18 E/F, MODSDF provided the same tool and flight control system to all functional disciplines instead of the variety of uncoordinated special purpose tools and models previously used individually. This practice allowed MDA (St. Louis) to check performance impact on the entire maneuver set rather than the isolated checks on only limited portions of the set. This resulted in a 50% to 90% reduction in the time required to identify critical points.

Other benefits of MODSDF include improved communication between disciplines and rapid assessment of synergistic effects, higher quality simulations due to uniform use of validated methods resulting in more highly integrated designs, a broader scope of analysis capability than single purpose simulation tools, and faster manned simulator checkout and verification.

Parametric Evaluation of Loft and Other Surface Data

MDA (St. Louis) uses a parametric evaluator to facilitate the exchange of loft and other surface definition data with incompatible CAD systems. This evaluation results in no loss of definition or accuracy of the original data. This standardization method represents all curves by one generic mathematical view, and all surfaces are also represented by one mathematical view. Parametric evaluation is the application of these mathematical procedures to precisely present the real space representation from the parametric representation.

Exchanging geometric (or loft) data between differing automated applications requires a data conversion to accommodate different algorithms used by different vendors and applications. Because this conversion introduces difficulties such as discontinuities, overlaps, intersections, and data expansion, MDA (St. Louis) creates or requests executable modules that enable it to use the loft data from 80 different applications without having to convert it. Some of these executable programs are proprietary; MDA (St. Louis) consequently does not have access to the code. The original native data is used, but the algorithms are translated by the modules into the standard generic

mathematical formula for curves and a standard generic mathematical formula for surfaces. This enables MDA (St. Louis) to access loft data from a variety of applications and CAD systems and use the data without a continuous evaluation of each use since the approach has been fully validated for each executable module and application.

Product Data Management

MDA (St. Louis) has linked disparate systems such as CAD, tooling, numerical control code, and a control and release system into a product data management system that provides access to a wide variety of data (Figure 2-5). The control and release system manages assembly layout packages and build-to-data packages on IBM, DEC and HP/Sun systems.

The experience gained in linking these different systems and environments has enabled MDA (St. Louis) to also link external partners into its system, rendering the access of data almost seamless. The system not only allows users access to the design data for a product at various stages of the development cycle, it also allows them access to configuration control of individual products by serial number. This new capability has significantly improved logistic operations. Approximately 50 gigabytes of digital product data are stored on magnetic media, with another 70 gigabytes stored on optical media.

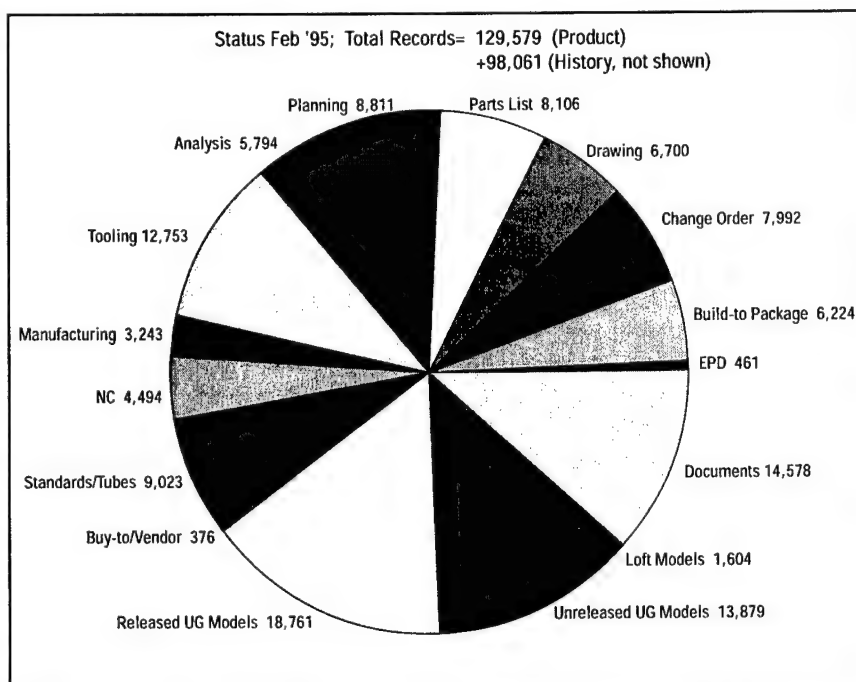


Figure 2-5. F/A-18E/F Control and Release System Product Database Records

MDA (St. Louis) used requirements from its DOD programs to guide evaluation of commercial Product Data Managers, resulting in selection of a product from the Sherpa Corporation. Integration of the Sherpa product into the MDA environment, and use of this capability for the management of Build-To Package data on production aircraft programs, has provided experience which is guiding MDA (St. Louis) to expand the use of the Product Data Manager to other types of program data, and to seek a corporate site license for broader deployment of this capability.

MDA (St. Louis) has used the experience gained in the creation of the internally-developed product data management system to evaluate commercial products. It has refined requirements from this experience and introduced the use of a commercial product data management system on upcoming MDA (St. Louis) product lines.

Software Processes

MDA (St. Louis) instituted three new processes to help define and manage software development to lower the risks and make software development more affordable. Historically, this development was a poorly defined and unreliable process and usually resulted in significant schedule slips and cost overruns.

The first of these processes is software planning and management, and it includes all activities necessary to start new software projects and manage the development process. The process is based on the Software Engineering Institute's certification program and has been certified Level 3 (Figure 2-6). Certification at this level requires that repeatable standard processes be used throughout an organization. This includes a process improvement plan for Level 4 and Level 5 certification and process improvement metric tracking. It is documented in a Software Engineering Process Manual, a Software Engineering Metrics Manual, and supporting Model Process guidebooks.

Model Processes are based on MDA (St. Louis) internal practices which have proved to be successful on past projects. Examples of Model Processes include Software Estimating, Risk Management, and Subcontract Management. Software Estimating includes the use of multiple estimating methods and a process for reconciliation of results. Software Risk Management includes risk assessment, analysis, abatement and tracking. Software Subcontract Management includes definition and planning, evaluation criteria, reviews and coordination, and supplier monitoring and management. Each Model Process is fully documented.

The second process is the Software Development Process which is based on MIL-STD-2167A life cycle activities. This process includes peer reviews, integrated software test

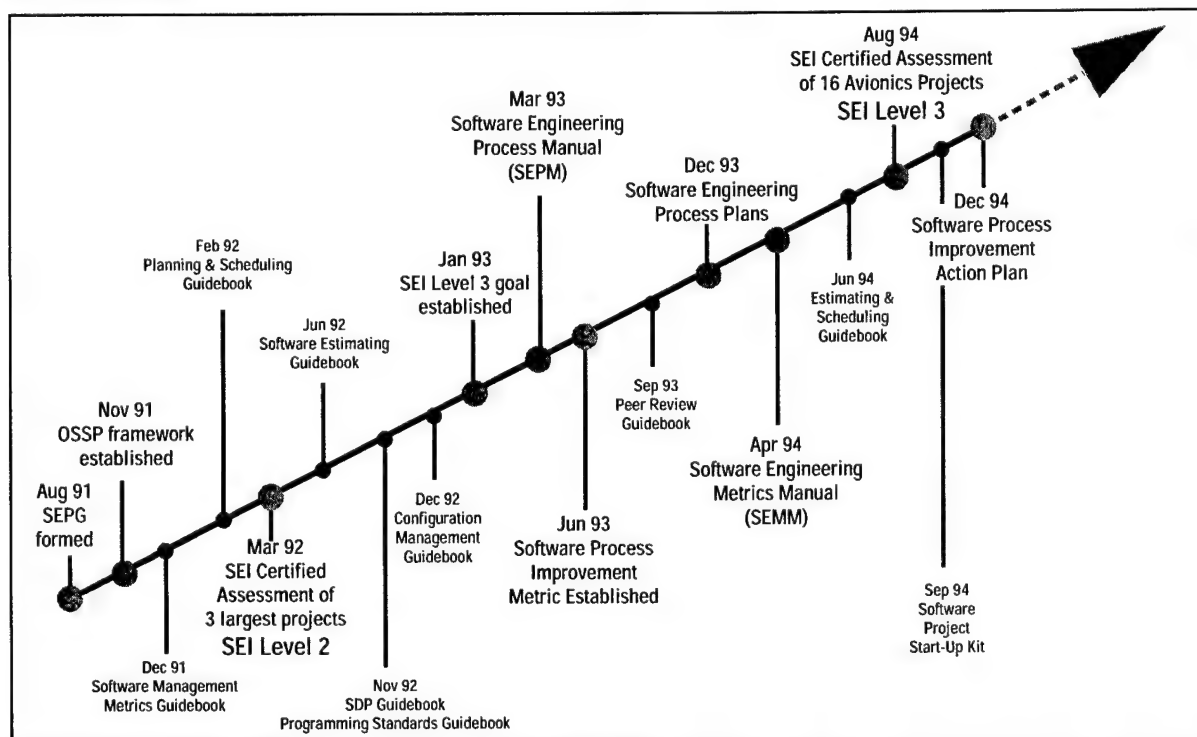


Figure 2-6. Software Process Improvement History at MDA (St. Louis)

planning and test development, configuration management, risk assessment, and software quality assurance standard practices.

The last process pertains to the software environment. This involves computer systems and software required to support software development. It includes long range strategic software engineering environment planning for the definition of requirements and acquisition of components in order to reduce duplication and promote commonality within MDA (St. Louis). There is also a software tool evaluation and development process to control the potential proliferation of very specialized tools and skills.

MDA (St. Louis) provides orientation and training of these software processes for all development personnel.

System Engineering Trade Study

MDA (St. Louis) reengineered its trade study process to improve the product and response time to its internal and external customers. Based on a description of what should be included in a trade study (Table 2-1), MDA (St. Louis) surveyed its high priority customers to determine further requirements for an exemplary study. Responses cited the need for such studies to be accurate, timely, objective,

Table 2-1. Trade Study Product Characteristics

In order to meet customer quality requirements, each Trade Study conducted within Product Definition is expected to be characterized by a consistent set of elements which include . . .

- Clear Problem Statement
- Identification of Requirements that must be achieved
- Ground rules and assumptions
- Decision criteria
- Resource requirements statement (Source/man hours required)
- Schedule to accomplish (Proposed and actual)
- Potential solutions and screening matrix
- Comprehensive array of feasible alternatives
- Comparisons of alternatives using decision criteria
- Technical Recommendation of Trade Study Leader
- Documentation of Decisions Leading to Recommendation

thorough, complete, have a consistent format, be documented, present a range of options, and provide a technical recommendation.

The MDA (St. Louis) trade study process has been thoroughly modeled and brought under a control process that ensures that studies are timely and of a consistently high quality. Scheduling planning extends down to requiring that study documents be delivered to participants before meetings to allow sufficient time to review the progress of the study results. Personnel involved in the process know

what problems they are to address, who it should be coordinated with, and when they are expected to conclude the study.

Technical Performance Measurement Process Improvement

MDA (St. Louis) successfully applies a Technical Performance Measurement (TPM) process to monitor how a program is progressing with respect to the customer's technical requirements. By measuring Technical Performance Parameters (TPPs), the TPM provides an excellent predictor of the customer's product satisfaction.

The TPM process begins by allocating baseline TPPs to the lowest applicable design level, which could be the subsystem level or the component level, depending on the application. After TPPs are allocated, they are monitored by rolling up requirements to the system level. TPM allows the program manager and the customer to check the status of a program with respect to technical requirements and determine where corrective action is needed.

TPM/TPP data is tracked through the Integrated Management Information and Control System (IMICS) which ensures TPM information is available to all levels of management at MDA (St. Louis). TPM/TPP products meet very stringent quality requirements. Therefore, the data input into IMICS must meet multiple criteria to ensure the TPM report is highly accurate.

To accommodate the customer's request to deliver the TPM/TPP information more quickly, MDA's (St. Louis) director of F/A-18 Product Definition challenged his team to reduce TPM/TPP product delivery cycle time by 10 days while maintaining the current quality and cost standards. Meeting this goal would require a 35% reduction in the existing process cycle time.

The F/A-18 team found an innovative way to reduce the cycle time without disturbing an effective process. The team published "preview" data to give the customer an earlier look at the report. This data represents the configuration as it appeared when locked in at the start of the TPM/TPP reporting cycle. Although the recommended changes and updates are reflected in the report, they may not actually be approved. Once approvals are received, a final TPM/TPP product is delivered to the customer.

By implementing "preview" reports, MDA (St. Louis) has effectively reduced the TPM/TPP monthly update delivery cycle time by 14 days for weight data, 7 days for Design-To-Cost/Life Cycle Cost data, and 5 days for reliability and maintainability data.

Variation Simulation Analysis

MDA (St. Louis) uses Variation Simulation Analysis (VSA) to accurately predict and minimize variation in its

products. This capability allows evaluation of alternative aircraft design and process concepts to facilitate the selection of optimum designs based on function, assembly processes, and cost constraints.

The variation simulation process includes four basic steps, beginning with inputting part geometry using an appropriate translator such as IGES. Part assembly tolerances and process capabilities are then identified, and the assembly sequence is defined as a tree structure. Finally, critical measurements associated with key product characteristics are identified. A Monte Carlo simulation is then run in which feature dimensions are randomly varied based on the tolerance, process capability, and assembly sequence data. A number of reports can be generated to provide information on the number of parts expected to be out of tolerance, and to identify the level of contribution of different part features and assembly processes to those failed parts (Figure 2-7).

VSA provides a substantial benefit in verifying design quality using software instead of the more costly fabrication

process. Other benefits include improved ease of assembly; more rational assignment of tolerances based on assembly process constraints; and an ability to consider cost tradeoffs associated with lowering tolerances, improving processes, or reworking parts. For example, MDA (St. Louis) staff conducted a transmission mounting analysis for a major aircraft design and determined that in-line and parallelism-of-holes tolerance, set at .001-inch, could be increased to .003-inch. Another application of VSA resulted in the assembly of the F/A-18 fuselage extensions without the use of shims.

Weapon Separation Analysis

MDA (St. Louis) has developed an integrated trajectory analysis software tool to model and simulate the path of weapons as they are released from the aircraft. This tool was developed to streamline the analysis process and to incorporate three-dimensional graphical visualization.

The original analytical methods required the development of an initial compatibility risk assessment based on

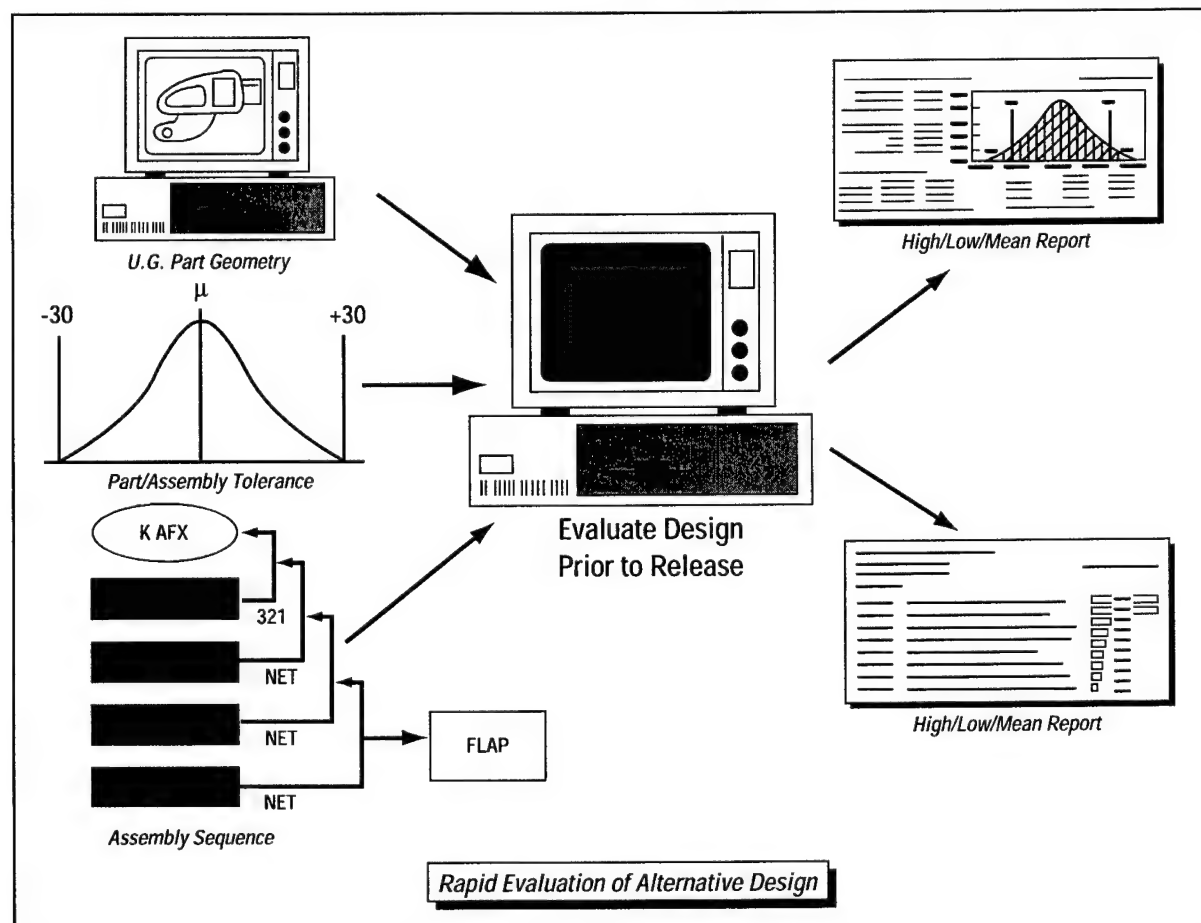


Figure 2-7. Variation Simulation Analysis

MIL-STD-1763A, study results, lessons learned, experience, and existing data. Wind tunnel and flight test plans were developed based on the initial compatibility risk assessment. The wind tunnel test plan included freestream, loads, flowfield, and trajectory. Actual flight tests were used to validate the database information. The wind tunnel tests were conducted, and a database was generated. The data and analysis were then sent to the customer, and based on the trajectory predictions, the flight test plans were refined and flight tests conducted.

The streamlining of this analytical process included reducing the number of file inputs, outputs, and file conversions; adding miss distance calculations for stores with movable sub-parts; eliminating standalone programs; and customizing the software. The three-dimensional graphical visualization included validating the miss distance geometry set-up, performing miss distance diagnostics, visualizing wind tunnel trajectories, visualizing flight test photometric trajectories, presentations to management and customers, and pilot briefings during the flight test program. These completed tools have been successfully implemented, resulting in lower risks associated with separation programs, and the number of flight test demonstrations required have decreased. The visual representation output of the system provides the means of visually describing the trajectory of the weapon as it is released and highlighting any problems.

Wind Tunnel Data System

MDA (St. Louis) uses its Wind Tunnel Data System (WTDS) to gather, manage, analyze, and display wind tunnel testing results. Volumes of wind tunnel data may be displayed and analyzed quickly resulting in time and cost reductions. Test data is analyzed on-site prior to the next run of a wind tunnel test. WTDS is used as a tool to diagnose suspected data problems. Run-to-run and test-to-test comparisons of test variables are provided. Report quality plots are generated. In-line users include laboratory test engineers, aircraft project engineers, data acquisition engineers, and wind tunnel operators. MDA's (St. Louis) wind tunnel facilities (polysonic, low and mini-speed, mass flow calibration, and nozzle thrust test stand) are on-line to the WTDS.

Production/Facilities

Automated Ultrasonic Scanning System

The Automated Ultrasonic Scanning System (AUSS) V is a computer-controlled ultrasonic scanning system designed to meet industry inspection demands for highly

curved, composite and metallic parts, and assemblies. The system, developed by MDA's Instrumentation and Design Group, has helped reduce inspection time, tooling costs, one-to-one flaw sizing, and improved data representation.

Nine axes of motion enable the unit to accurately follow complex curvature without part repositioning. Through transmission and pulse echo, data can be collected simultaneously during scanning of curved subassemblies due to accurate curve following. The system uses digital data imaging. Parts currently requiring multisegment scanning (up to 40 segments) can be completed in a single scan with the AUSS V. Typical parts and assemblies benefitted by this system include control surfaces, wing skins, and fuselage panels. The system inspects for defects such as delaminations, porosity, disbonding, voids, ply displacement, foreign material, and core defects.

Additional features of the AUSS V include conversion of three-dimensional to two-dimensional data which provides accurate location of anomalies in actual surface distance measurements. XYZ space part description allows complex scan paths to be calculated without machine axis dependence, resulting in fast, efficient scanning of complex surfaces. The AUSS V also includes a manual teaching capability, CAD/CAM part configuration interface, imaging in eight to 256 colors or gray shades, optical disk data storage, and vector and alphanumeric overlay annotations that can be electronically stored or in hard copy.

The AUSS V supports critical inspection needs such as providing reliable and repeatable inspections on critical structures, storing inspection data digitally for future reference, providing throughput needs to make inspection costs effective, and providing a means to inspect parts which could not be inspected manually due to their configuration.

MDA (St. Louis) is continually improving the AUSS V system. The next generation will be used to expedite the inspection cycle of the most demanding assemblies as parts become larger and more complex. New visualization software is being developed which will allow for a common database and improved access, promoting remote consultation on a PC-based system. MDA (St. Louis) is currently marketing the AUSS V and has sold systems to other major aerospace companies.

Computed Radiography

In September 1994, MDA (St. Louis) installed and began using the Fuji AC-2 Computed Radiography (CR) equipment. The company had historically been applying Non-destructive Testing (NDT) and evaluation techniques and had relied primarily on X-ray and ultrasonic methods in parts evaluation. Although these methods worked well, they did not provide the desired fidelity of data under certain

circumstances such as identifying titanium flange and composite layup bondline integrity.

CR technology is based on a filmless process which utilizes a reusable phosphorus image plate as the sensing mechanism. Like film, the image plate is placed near the specimen and exposed. Following exposure, the latent image is extracted from the image plate by the main image reading system. The image reader then digitizes the image plate's response and assembles a data file or frame. The complete process requires 1.5 minutes, in contrast to film processing which requires 8.5 minutes, and can be repeated every 15 seconds. Once read, the image plate is erased and may be reused. The digital data file produced by the reader is exported to an off-line imaging workstation where the CR data can be analyzed and stored.

CR represents feasible alternatives to industrial film for a significant number of inspection applications in the NDT labs at MDA (St. Louis). With the CR system, NDT setup time and cost is reduced, film handling and archiving are eliminated, film developing cost is eliminated, and environmental concerns of film processing are eliminated.

This technology has high utility, facilitates digital archiving of data, and allows magnification of associated images for easy inspection of critical features. The value of radiographic analysis is renewed because of the utility of CR data and a high degree of confidence in this radiographic technique. Future plans at MDA (St. Louis) include the formation of an NDT common database which incorporates CR data, ultrasound-C-scan data and rejection report data. Easy access to this common database will be provided to customers in satellite locations via remote communications.

Cutting Tool Development

MDA (St. Louis) has formed the Cutting Tool Development Group to evaluate both vendor standard cutting tools and/or designs in a laboratory environment. This group is also responsible for developing MDA (St. Louis) standard cutting tools to ensure that its customers are provided with the best performance-to-cost value on perishable cutting tools.

The laboratory is staffed with engineers and technicians who perform controlled experiments with different tool configurations, materials, cutters, and a variety of machines. This evaluation process results in the establishment of the process requirements to include the type of tool, the machining parameters, suggested cooling methods, and subprocesses. Once the process requirements are established, the work for the Cutting Tool Development Group will continue as process maintenance through evaluations for repeatability and cost effectiveness.

The goal of testing the cutting tools is to achieve a consistent level of performance which will result in better

utilization of manpower and machines in the manufacturing area, improve accuracy, give performance predictability, reduce scrap and rework, reduce perishable tool costs and inventory, and establish tool specifications and performance standards for cutting tool products and suppliers. The group works with the procurement department to establish a reliable supplier base for standard tools. When specifications are established defining performance criteria, procurement can reject non-conforming material.

Because there are many factors that have an influence on the machinability of a part, it is important to know where to begin. Predictable cutting tools must produce predictable results if machinery data is to be considered valid. Consequently, cutting tools must be inspected and accepted to an inspection document.

Perishable tools are a recurring cost. Poor tool performance equates to higher tool inventory and increased process maintenance costs. High performance tools lower inventory and process maintenance costs. The use of high performance tools provides MDA (St. Louis) with a competitive advantage in process maintenance and customer satisfaction.

The Cutting Tool Development Group ensures that high performance tools are available, at an equitable cost, at MDA (St. Louis) to meet the needs of production, thereby providing the company a competitive advantage and improved customer satisfaction.

Digital Photographic Visual Aid

MDA (St. Louis) uses a Digital Photographic Visual Aid (DPVA) to add annotated photographic quality images to work instructions. DPVA improves work instructions by providing realistic visual images that are easier to interpret than line drawings, and it can quickly produce either hard-copy or electronic images.

The DPVA process consists of videotaping a part or assembly and digitizing the image using a PC and related software. Annotations depicting part numbers, notes, or instructions can be added to the image using imaging editing software. A DPVA station consists of a VHS camcorder, VCR, color monitor, laserjet printer, access to a shared data server, and a PC with color monitor (Figure 2-8). Additional hardware and software are used to extract, annotate, and format individual visual aids.

The DPVA system, though currently working in color, is restricted to grayscale hard copy. MDA (St. Louis) will enhance the system by providing color hard copy, and by electronically transmitting both still and moving images to the workstation where they can be displayed in color. MDA (St. Louis) is expecting to significantly reduce the time to take, capture, and process a visual from the currently-required 20 minutes by increasing the power of the system.

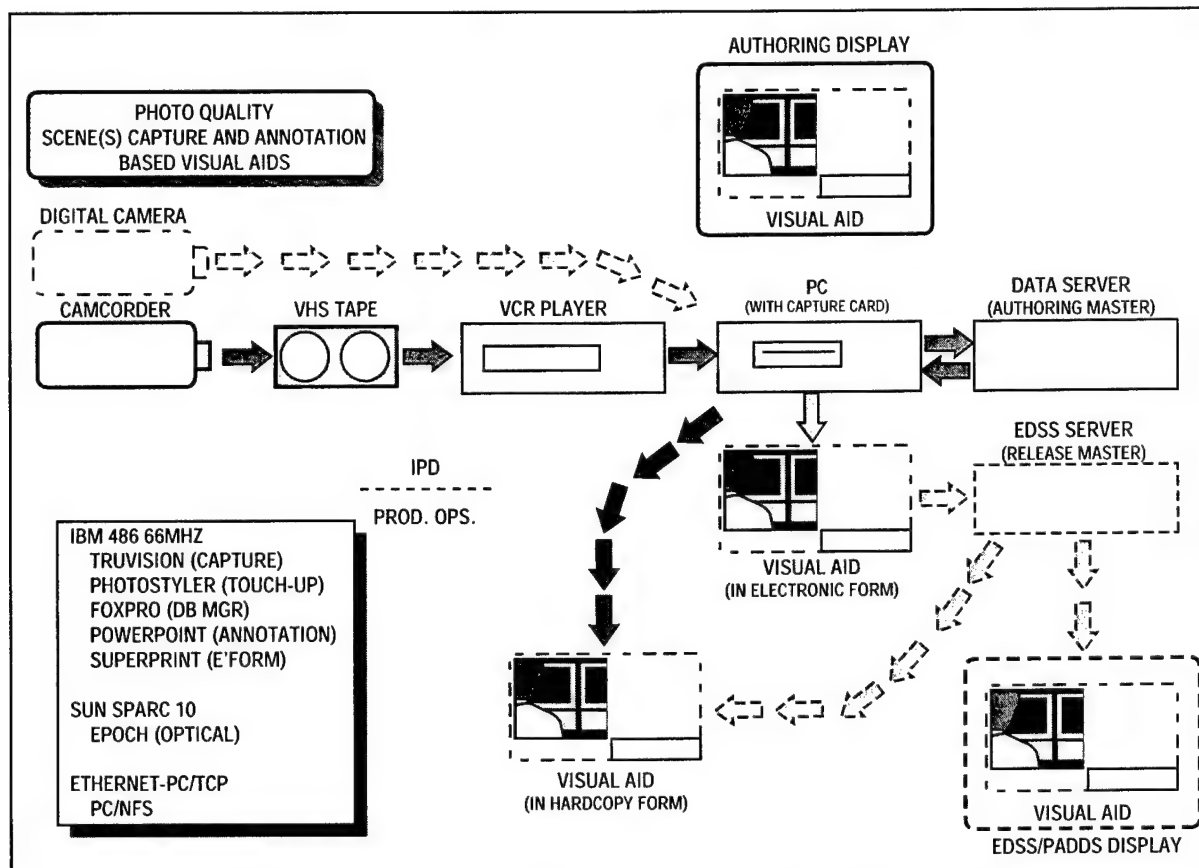


Figure 2-8. Digital Photographic Visual and System Process

Other improvements include producing sharper and higher-contrast images. To accomplish this, MDA (St. Louis) has been experimenting with digital still cameras.

Drivmatics with Large Parts Handling

MDA (St. Louis) helped develop machines required to meet the demands of automatically fastening large metal assemblies. Until 1987, MDA had no requirement for handling large metal assemblies, as its product line consisted of smaller aircraft. After receiving the nose section of the C-17 aircraft to assemble, the company realized the only method of riveting very large parts was manual, and the need to automate the process became critical.

Equipment acquisition consisted of three new, automatic riveters from GEMCOR, New York, and one five-axis positioner was fabricated in house. Two automatic riveters came from Douglas Aircraft Company Long Beach, two five-axis overhead parts positioners and one automatic riveter from Douglas Aircraft Company Columbus, all of which were acquired through an Intercomponent Asset Transfer. These large part positioning systems offer five-

axis, semiautomatic capabilities including indexing to the next fastener location and mold line surface normalizing, ensuring drill spindle perpendicularity and fastener flushness. Part clamping on the machine eliminates the need to disassemble and deburr the parts after the drilling operation. The Drivmatic equipment can select the proper grip length fastener for any given material thickness. It automatically applies sealant to the drilled hole, and installs consistently flush fasteners, thus eliminating all shaving requirements. Automatic positioning and fastener installation on large parts has resulted in a five-to-one labor savings compared to the old method of manually installed fasteners.

Electronic Work Order System

The Electronic Work Order (EWO) System, developed by MDA (St. Louis) as an Air Force MANTECH project, integrates manual and automatic shop floor processes with computer-integrated manufacturing planning, scheduling, and control.

The EWO runs on a DEC VAX cluster using McDonnell-Douglas developed software with text and graphic

windowing workstations, a custom keyboard, barcode data entry, and an optical archival system. The system schedules and tracks work for the Integrated Composites Center, using input from the Automated Planning System. EWO supplies an electronic package with the text and graphics required to accomplish the assigned task. It automatically updates information using the latest instructions and collects an audit-ready, as-built history. The system checks the work order for incomplete operations and open inspection sequence buy-offs. It maintains an audit trail of all time-sensitive material, and schedules work to use the material with the lowest remaining shelf life. The system collects and provides on-line visibility of labor hours expended and produced. It is also used by management to report on topics such as cycle times, hours remaining on parts when moved to cure, and part and material status.

EWO uses personnel qualification records and requirements to define user privileges to control, update, and sign-off on operations. Data entry on the floor is simplified through the use of barcode scanning and menu driven screens.

Environmental Improvement Initiatives

MDA (St. Louis) established the Environmental Assurance division to perform technical and business analyses for selecting the most cost-effective and lowest-risk compliance methods to meet environmental directives projected for the next seven years. The company is reducing its environmental impact by altering operations, some of which involve specific modifications to a single process or piece of manufacturing equipment, while others are broad, sweeping modifications to the daily corporate operations. To ensure that all perspectives are reflected, multidiscipline

The Directives Review Committee is a standing committee comprised of OSHA and environmental representatives who use a disciplined process to review and prioritize requirements. It reviews and maintains all environmental requirements (federal, state, and local environmental regulations, contrac-

tual stipulations, and corporate policies) in a corporate database. It then identifies required improvement initiatives and prioritizes the improvement initiatives.

The Technical Review Committee then performs business case analyses (options evaluations, risk assessments, and cost estimations) on the prioritized initiatives, selects a preferred option, develops an action plan for each initiative, incorporates the action plan into an Environmental Assurance strategic plan and forwards recommendations to the Executive Review Committee for further action.

The Executive Review Committee analyzes the Technical Review Committee recommendations, discusses alternatives, risks, and other topics; provides enlightenment on future corporate direction, initiatives and policies; and approves/disapproves the recommendations. At this point, corporate commitment for funding of the initiative is made.

Through this disciplined approach, MDA (St. Louis) has been able to implement the majority of environmental initiative projects at the lowest cost option. By doing so, it has been more proactive in the environmental compliance arena, and can maintain the affordability of its products.

Finite Element Model Weight Estimation

The MDA (St. Louis) Finite Element Model Weight Estimation System (FEMWTS) is a set of management software tools used to track, estimate, and control airframe weight early in the design process when changes are easy and inexpensive to implement (Figure 2-9). Design parameters include structural arrangement, material properties, air loads, dynamic requirements, panel optimization, and thermodynamics.

FEMWTS provides management with the information required to allocate resources to achieve inexpensive,

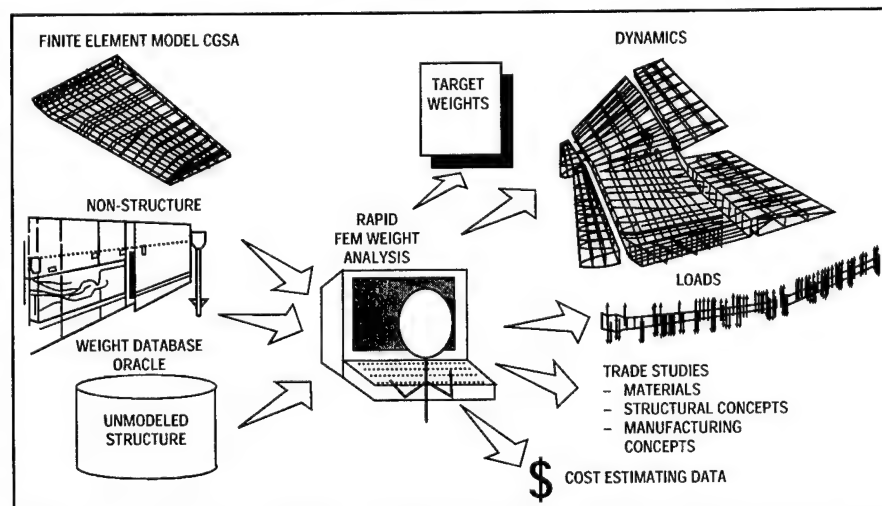


Figure 2-9. Finite Element Model Weight Estimation

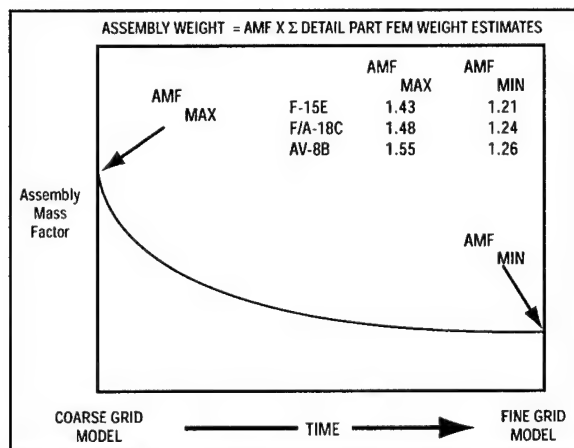


Figure 2-10. Assembly Mass Factor Rapid Estimation Capability

lightweight airframes. This estimation process consists of three steps.

1. Transforming the strength model into a mass model using reduction algorithms.
2. Estimating detail part weight using detail part algorithms and mass factors.
3. Estimating assembly weight through the addition of assembly mass factors for joints, splices, and fasteners.

Estimated assembly weight is computed by multiplying an assembly mass factor by the sum of detail part finite element model weight estimates. As the estimation and design processes continue to refine weight estimates, the assembly mass factor (a correction factor) approaches a value of 1 (Figure 2-10).

FEMWTS has enabled MDA (St. Louis) to generate estimates previously requiring up to several weeks, in minutes. The capability has been used on several programs with a high degree of estimation accuracy such as the F/A-18 E/F fuselage, wing, and tail sections (+.7% error in estimate from actual weight); the Advanced Short Takeoff Vertical Landing aircraft composite fin (3.8% error), and YF-23 wing carry-thru bulkheads (-0.6% error). It has also allowed MDA (St. Louis) designers to make more effective design trade-off decisions regarding weight and structural strength.

Fire Services 24-Hour Shift

In an effort to control rising costs, reduce the need for overtime and provide improved services, MDA (St. Louis) Fire Services has transitioned from a traditional 8-hour workshift to a 24-hour shift, patterned on the surrounding public fire service agencies.

A joint Fire Services team comprised of labor and management was tasked with benchmarking similar operations at Hughes Aircraft, Federal Express, and local public fire departments. Issues on compensation, labor accounting, and other topics were addressed by an intradepartmental team who determined that the payroll program changes to accommodate the twenty-four hour shift would include a one-time cost of \$40K. Based on the data collected by the teams, it was decided to implement the twenty-four hour shift for Fire Services at an initial investment of \$160K which included the cost for the physical enhancements of the firehouse facility as well as the costs associated with the reclassification of the fire fighters from FEP Hourly to Non-Exempt Salaried. Approval for the implementation was obtained from all pertinent management in about three months.

Instituted in October 1993, the return on investment was realized in just 14 weeks. Annual labor savings from overtime reduction amounted to \$661K. Total annual cost savings/cost avoidances amounted to \$1.38M. Other benefits included increased manpower coverage for less costs, improved service delivery, and improved morale.

By maintaining the same work shifts as the departments in the surrounding communities, MDA (St. Louis) is now better able to coordinate training and emergency services as well as provide a consistent level of manpower around the clock.

High Pressure Guerin Forming Process of Aluminum Sheetmetal

MDA (St. Louis) applies guerin forming, or rubber pad forming, to improve the quality and producibility of sheetmetal parts. This method involves high pressure forming and utilizes a rubber pad inside a chamber to apply pressure on metal blanks placed over tools. The pressure on the blanks forms them around the tools.

The MDA (St. Louis) machine, built by Siempelkamp Press Systems in Germany, has been used in production since June 1989. It is a 25,000-ton press with up to a 30,000 psi forming pressure. It has four operating stations with two pallets per station, and all eight stations can be concurrently loaded into the system. This press is the only 30,000 psi rubber-pad type, high pressure forming facility in the world. It has a capacity of one million parts per year based on a two shift, five-day-a-week operation. The cost of the machinery was \$4.3M, and installation was \$710K.

The higher forming pressures result in fewer press hits to manufacture an acceptable part. One hit is normally required instead of two or three using the previous method at lower pressures, and little rework is required. A reduction of up to 80% in rework time and 60% in cycle time can be achieved by using this high pressure forming method.

High Speed Machining System

MDA (St. Louis) considers High Speed Machining (HSM) a critical technology which addresses part design flexibility, weight savings, part accuracy and part quality, all accomplished while maintaining a high degree of productivity. At MDA (St. Louis), HSM represents surface cutting speeds in excess of 1300 feet per minute (fpm), and feedrates exceeding 100 inches per minute (ipm). Presently, the company is using HSM to fabricate machined parts to replace sheetmetal assemblies with numerous labor-intensive pieces.

The MDA (St. Louis) cutting process significantly reduces the cutting forces to operate at ten times normal speeds and feeds for cutting aluminum parts. MDA (St. Louis) maintains a goal producing lighter weight parts with thin cross sections and smaller radii with better quality, increased productivity, increased design capabilities, and lower production costs.

To better understand HSM technology, MDA (St. Louis) established a laboratory with a Rambaudi 2000 vertical milling machine which was retrofitted with an IBAG 20,000 rpm, 50 HP spindle, with feedrate capability of 236 ipm.

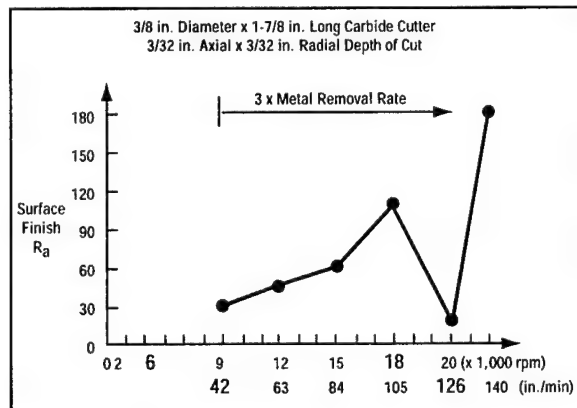


Figure 2-11. Surface Finish vs. Speed

One experiment used 20,000 rpm and a 126 ipm feedrate, and achieved a surface finish of 180 radium. The second cut was at 6,000 rpm and 42 ipm with results of a 30 radium finish. Feeds and speeds were increased in incremented amounts (Figure 2-11).

MDA (St. Louis) has found that HSM creates lower cutter forces on the work piece which results in the ability to have reduced rib and web thicknesses, smaller corner radii, reduced tolerances, superior surface finishes, reduced residual stresses/distortions, and a high material removal rate. For these reasons, MDA (St. Louis) expects to replace sheetmetal sub-assemblies with a one-piece, HSM aluminum plate, resulting in reduced assembly time, fewer fabri-

cation tools, and lighter parts which are stronger and less expensive.

MDA (St. Louis) will increase the use of HSM in the future because it can maintain a high metal removal rate, produce complex parts cost effectively, and reduce the use of multiple part assemblies.

Integrated Assembly Management Process

The objective of the Integrated Assembly Management Process (IAMP) at MDA (St. Louis) is to lower the total cost of the assembly process. IAMP consists of assembly knowledge acquisition, multiprocess integration re-engineering, constraint-based scheduling, and optimum resource deployment.

The assembly knowledge acquisition process represents a key reason behind IAMP's success. This process is documented through precedence diagrams to identify assembly sequence requirements. Other constraint information is also documented such as aircraft zone access needed, tooling requirements, and assembly instruction data sets. This data allows IAMP to synchronize application of resources to the assembly process and ensure work zones are available when work is scheduled. In one case, the number of mechanics required to support an assembly process was reduced from 10 to 5, based on zone access limitations.

IAMP was used in a major aircraft program in late 1993. The first constraint-based production schedules were created in early 1994 and applied to the build process in mid-1994. As a result of the improved scheduling of IAMP, aircraft assembly time was cut in half (from 32 to 14 days), 5000 square feet of high bay floor space was released for other uses, and 0.8 aircraft were removed from the production flow, saving \$7.9M in work-in-process and reducing carrying costs by \$1.6M.

Intelligent Wire Assembly Station

MDA (St. Louis) has developed and successfully implemented a computer-aided system for connecting wires to their respective electrical connector pinholes. The benefits achieved by the new system – the Intelligent Wire Assembly Station (IWAS) – over the superseded Work Director System include a 95% reduction in programming time, a 15% increase in productivity, creation of a paperless operation, and the flexibility to interface with other shop floor systems.

The worker is first shown the computer screen general assembly notes, parts lists, tooling requirements, and splicing details. Next, a connector graphic file from the computer library is displayed on the screen. The display depicts the wire number, color and gauge, and the pin number to

which it should be connected. The pin number and the appropriate pinhole connector display blinks with the color of the wire to be connected. The display also shows the unused/spare pinholes in a solid color different from the wire colors. After all wires are connected, IWAS checks if there is any splicing, and then graphically indicates how the wires are to be spliced.

IWAS can accommodate wire splicing on 98 connector types and over 200 wires per connector. The sequence of hole numbers can be arranged in a linear, circular, or spiral orientation. Additional capabilities include the:

- ability to change assembly sequences with just a change in the data file;
- ability to show previous operations;
- ability to handle a small batch job with no programming;
- automatic generation of splicing graphics;
- capability to walk forward and backward while assembling wire; and
- reliability of near 100%.

Large Extrusion Contour Roll Forming

MDA (St. Louis) has installed a precision contour roll machine system that is capable of rolling and forming complex shapes in long extrusions of uniform or variable thickness and unlimited length (greater than 3 feet). Previous operations to shape these long extrusions had to be accomplished manually using complex stretch dies, and were dependent on the skill and experience of the mechanic.

In 1993, MDA (St. Louis) obtained a 6-axis, CNC-controlled contour rolling machine from a sister division. Only one of five in existence, the machine was constructed by L&F Industries, Huntington Park, CA. It was refitted with new controls that utilized a 486 PC with Windows-based software in the fourth quarter of 1994. This upgrade significantly improved the accuracy of the machine and increased its capabilities to accurately measure the length of the extrusion as it is fed through the rollers, thereby ensuring exact bend locations throughout the entire length of the part.

With a maximum capacity rated at section modules of 4 inches by 4 inches by 3/16-inch thick in mild steel, the machine is capable of rolling parts with complex shapes extruded from aluminum, steel and titanium. Structural sections that can be contoured include tees, angles, zees, channels, jays, hat sections as well as pipes, rods and heavy wall tubing. Current application of the machine includes programming parts at the machine using CNC control and storing the data for future repeat operations. Future plans include downloading the part's engineering data directly into the machine control.

Low Cost Composite Tooling

With the Department of Defense (DOD) purchasing fewer items, MDA (St. Louis) started a program aimed at reducing the cost of producing composite curing tools. The cost of tooling to cure composite parts in a harsh autoclave environment has traditionally been high. However, in the past this cost could be spread across relatively large production volumes making the impact on unit cost less significant.

Curing tools are normally made from steel, aluminum, or electro-formed nickel to withstand the heat and pressure of an autoclave. These tools are expensive, have long lead times, are size limited, and require intermediate tooling. High temperature composite tooling is one alternative to these metallic tools; however, it has several drawbacks including durability problems, long lead times, and a requirement for intermediate tooling.

To solve these problems, MDA (St. Louis) developed a new composite curing tool manufacturing process using arc-sprayed metal. This process utilizes a low-cost tooling form over which atomized molten metal is sprayed to form a thin metallic layer (Figure 2-12). This layer can then be removed from the original form and backed with a low-cost support structure – such as sprayed chopped fiber/resin – to add strength. The result is a low-cost, short lead time, high durability composite curing tool.

A tool has been manufactured in this manner for the AV-8B aircraft fuselage side panel. This tool was made for 34% less cost than the original electro-formed nickel production tool. MDA (St. Louis) is now preparing to manufacture the first flyaway production side panel on the arc-sprayed tool.

MDA (St. Louis) is working on an Advanced Research Project Agency-funded program to carry this process further. This program is planned to develop the capability to automate the process of NC programming and CNC ma-

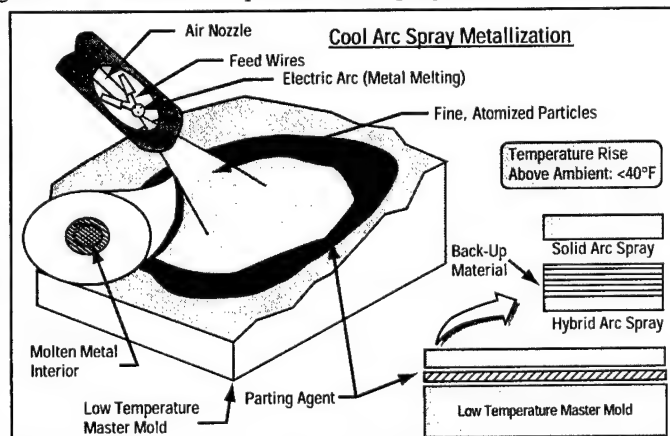


Figure 2-12. ARC Sprayed Tool Fabrication Technology

chining low cost master models. From the master model, a robotic metal arc-spraying system and robotic chopped fiber/resin spraying system will manufacture the composite curing tools. These process improvements will further reduce tooling costs at MDA (St. Louis).

Low Rate Expandable Tooling

A new concept being applied in MDA (St. Louis) in the F/A-18 E/F assembly process is Low Rate Expandable Tooling (LRET) that reduces the total number of tools required to assemble a major aircraft assembly at a low production rate. This approach offers many advantages over conventional assembly where subassembly tools feed a sequential assembly process. MDA (St. Louis) is using the LRET approach on the F/A-18 E/F forward fuselage and wing assemblies, and MDA's partner for this aircraft, Northrop, is also using the approach on the center barrel and vertical fin assemblies.

The LRET concept calls for fabrication of a small number of large mainframe assembly jigs and a larger number of assembly locator tools, referred to as Assembly Jig Accessories (AJAs). These removable AJAs are used to locate primary aircraft structures when pinned to a mainframe jig, and are designed to be interchangeable with mainframe jigs. This concept minimizes duplicate tooling requirements. In addition, the practice of locating the AJA tools to the mainframe provides the added benefit of reduced tolerance build-up, reduction in jig lock caused by part shortages, and improved quality.

As in the F/A-18 E/F program, developmental flight test programs typically result in minor aircraft configuration changes that drive corresponding changes to assembly tooling. A reduction in tooling rework is anticipated since minimum tooling is required for the Engineering and Manufacturing Development phase of the F/A-18 E/F acquisition program and the AJAs are removable. With over two years of hands-on experience with the LRET approach, MDA (St. Louis) has thoroughly addressed manpower loading, impact of late parts, and the quality of the assembly produced through successful aircraft splice.

To date, the LRET approach has been used to assemble four F/A-18 E/F aircraft and is performing well above MDA's (St. Louis) expectations with a 21% savings reported in up-front tooling costs.

MODIG Extrusion Router/Driller

Many aircraft components are fabricated from aluminum extrusion material, and to economically machine these parts is a critical factor in controlling costs. MDA (St. Louis) is addressing this issue by investing in state-of-the-

art machine tools that perform complex, labor-intensive operations automatically.

The MODIG Extrusion Router and Drill machine performs milling, drilling, and profiling on aluminum extrusions using CNC controls, high speed machining technology and universal material holding fixtures. Built in Sweden, this five-axis machine has four linear axes and one rotary axis. It is equipped with an IBAG high frequency 40,000 RPM spindle and can machine at a feed rate greater than 300 ipm. It has a 24-station tool carousel with an automatic tool changer and dynamic tool tracking. The extrusion material in-feed and out-feed is automatic with a nine-station, indexable in-feed magazine. With the capability of performing all profile, mill, and drill operations on all surfaces of the extrusion for any part length ranging in size from 1/4-inch to 40 feet makes this machine a valuable asset in the fabrication of longerons.

Once the parts have been machined on the MODIG, they are automatically deburred on the VIKAT Profile deburring line. It is a fully enclosed deburring system of six polishing wheels for each surface of the extrusion and six abrasive cloth "fladder" wheels to radius all the edges of the machined part. The extrusion is fed through the system automatically by means of power drive wheels. The speed of the individual abrasive wheels can be controlled by independent variable speed motors. The polishing wheels are applied to the extrusion by pneumatic cylinders and are equipped with wear indicators. Adjustments for the different extrusion cross sections are made manually.

The time savings realized in the machining and deburring operations for the manufacture of the longerons used on the C-17 aircraft have been calculated as an average time for each operation based upon review of 508 parts. These savings amount to 6.88 hours per part. To date, 469 of the 508 parts have been programmed for the system.

Paperless Material Review/Corrective Action System

MDA (St. Louis) is installing an automatic material review and corrective action system to be completed by the end of 1995 (Figure 2-13). The automated system is based on core software procured from Andersen Consulting. The Nonconformance/D software is compatible with existing company component systems from the Missiles division, Space and Transport Aircraft division, other companies, IBM computer system, and with MacPac/D (MRPII) or standalone systems. The reporting capabilities are presented in Figure 2-14.

Noncon/D is an automated system that provides real-time, non-conformance status, electronic data transfer and routing, on-line work queues and metrics, on-line corrective

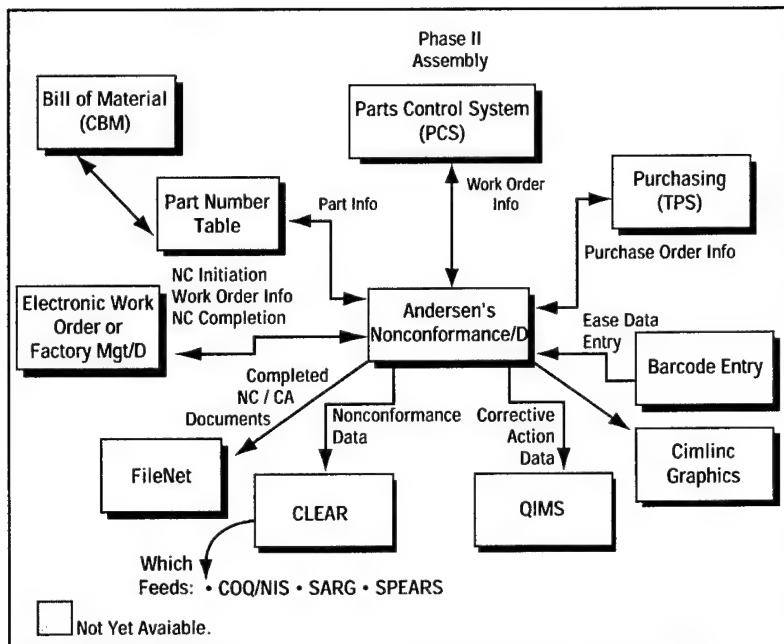


Figure 2-13. Planned Interfaces to Nonconformance/D

action tracking, reporting and follow-up, automated archiving, field level security for electronic buy-offs, and occurrence and recurrence analysis capabilities. This system has answered an MDA (St. Louis) need for a non-conformance graphics capability. Other benefits of the system to MDA have been realized in all areas of the non-

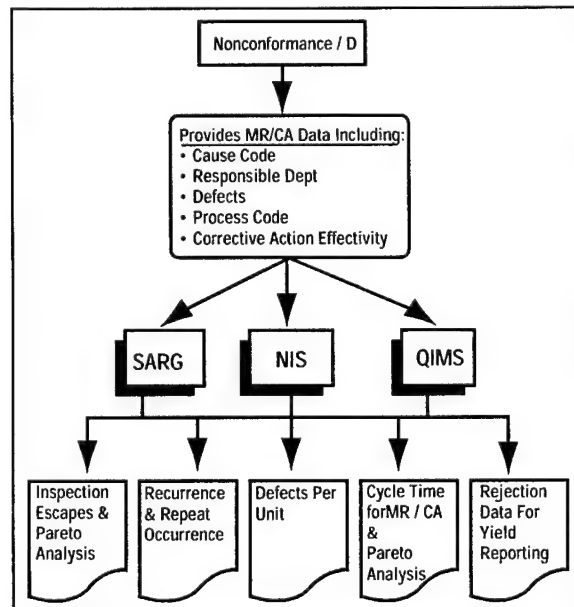


Figure 2-14. Reporting Capabilities with Paperless Material Review/Corrective Action

conformance and corrective action process. Principal advantages included:

- elimination of the paper trail that was labor intensive, time consuming, and costly;
- reduction of cycle time and work-in-process;
- enhancement of a consistent material review process;
- enhanced control of non-conforming material;
- readily-available, real-time reporting at any terminal;
- improved customer satisfaction.

MDA (St. Louis) plans to use the system to provide historical data to analyze quality problem areas. Trends will be identified revealing design/manufacturing quality problem areas. Resolution of these problem areas could prevent future quality problems.

Preferred Supplier Certification Process

MDA maintains a supplier certification process to establish long-term partnerships with suppliers. These relationships, in turn, enable MDA to satisfy its customers with top quality, technically excellent, affordable products that are delivered on time. Currently, 494 suppliers have been certified at one of three levels. This certification process has focused on the complete business process, accelerated product and process improvements, and strengthened teamwork between MDA and its suppliers. Currently 494 suppliers have been certified at either the Bronze (385), Silver (103), or Gold (6) levels.

There are three major elements to the supplier certification process including assessment of supplier business processes, SPC, and supplier performance management (Table 2-2 and Table 2-3). A team assessment is conducted of a supplier undergoing certification. The assessment process looks at management, quality, technology, cost, delivery, and customer support criteria. The statistical process control component of certification requires a documented SPC implementation at the Bronze level; critical processes and control characteristics identified at the Silver level (as well as a manufacturing process capability C_{pk} of > 1.33 and a plan to reduce variation in non-conforming processes); and improved process capabilities, utilization of SPC, and a philosophy of continuous improvement at the Gold level. The Supplier Performance Evaluation and Rating System (SPEARS) process is used to measure quality

Table 2-2. Preferred Supplier Certification Process (SPC Requirements)

Bronze Level	Silver Level	Gold Level
1. Documented Implementation Plan with Milestones	1. Critical Processes and Control Characteristics Identified	1. SPC Utilized in Manufacturing and Business Operations
2. Verification of Initial Implementation	2. Evidence of Process Control	2. Evidence of Process Control
	3. Manufacturing Process Capability of Cpk >1.33	3. Minimum Cpk of 1.50 on Critical Processes
	4. Monitoring of Non Capable Processes	4. Monitoring of Non Capable (Non Critical) Processes
	5. Plan to Reduce Variation of Non Capable Processes	5. Plan to Reduce Variation of Non Capable Processes
	6. Philosophy of Continuous Improvement	6. Philosophy of Continuous Improvement

in terms of acceptance rate and cost of quality, rate of on-time delivery, and supplier responsiveness.

MDA has not only implemented the certification process with its suppliers, it has implemented it within its own manufacturing centers as well. It has developed a comprehensive supplier certification manual that is provided to all candidate suppliers as a basis for initial self-assessments. Four of five internal production centers undergoing certification have reached the Bronze level.

tential replacement processes are ranked using the QFD matrix.

When the leading candidates are identified, the team attempts to lower the risks of these methods even further by performing trials on non-production parts, running laboratory tests, or performing Taguchi testing. When the team agrees that the process is ready for production and meets the QFD requirements, shop trials begin on production parts. Shop trials are always required, even if the process is proven at other facilities, because each facility is unique.

Table 2-3. MDA Guidelines Summary of Standards for Certification

Certification Level	Assessment of Process		Performance (2)			
	Total (1) Business Assessment	Statistical Process Control (SPC)	Quality		Delivery	
			Acceptance (%)	Period Months	On-Time (%)	Period Months
Gold	4.5 - 5.0 Min 4.0	Certification of SPC Facility-Wide	100	12	100	12
Silver	3.5 - 4.4 Min 3.0	Certification of SPC on Critical Processes	98 - 99	12	95 - 99	6
Bronze	2.5 - 3.4 Min 2.0	Certification of Initial SPC Implementation	95 - 98	12	90 - 95	6

Notes: (1) Assessment of management, quality, delivery, cost, technology and customer support process.

(2) Performance guidelines may vary with product complexity.

Project Deployment: Technology Transition to Production

Because current and future environmental regulations have an impact on manufacturing, MDA (St. Louis) devised

Low Vapor Pressure Solvents. MDA (St. Louis) began replacing trichloroethane (TCA) by establishing a natural work group comprised of people involved in operations that used TCA. This group selected several low vapor pressure solvents as replacements. Several were needed as no single

a way to change production processes to comply with the regulations with the least amount of risk to the production programs. This was accomplished by using a multidiscipline team approach to generate solutions and determine their workability.

These multidisciplined teams include all personnel affected by the new regulations. Customer concerns (internal and external) are taken into account, and all aspects of the current manufacturing method that would be affected are noted. Requirements for the replacement process are obtained using Quality Function Deployment (QFD), and the po-

Each affected process is tested, and each trial is supported by the team across all shifts. The process is monitored and corrective action taken until it meets all requirements and is production-ready. The team, or a third party, monitors the process performance to ensure project objectives have been met.

This method has been used successfully on several programs, including ozone-depleting substance elimination and compliant coatings. Not only did the new processes not have an adverse impact on manufacturing, in some cases they produced improvements and cost savings. These improvements are highlighted by the following examples.

solvent could be determined to duplicate all TCA's capabilities. However, these replacement solvents could be used at lower vapor pressures; they had slower evaporation rates resulting in a significant reduction in the required material; and approximately 70% less material was required as compared to TCA. These resulted in a cost impact of a 40% material cost saving or \$14 per gallon.

Non-destructive Testing. The non-destructive testing penetrant developer used to detect cracks was changed in 1995 from an ODS to a non-ODS dry powder material. The annual cost of the ODS was \$7.6K, and the estimated yearly cost of the dry powder was \$1.4K, resulting in a year cost saving of approximately \$6.2K.

Rotational Molding Process

MDA (St. Louis) has adopted and adapted a manufacturing process that has been extensively used in the toy and automobile industry for years. Using this process, known as rotational molding, on Environmental Control System and crew station aircraft ducts, initial tooling costs were lowered, and the process eliminated the need to fabricate a tool each time a part was built.

Traditionally, the ducts were fabricated out of Kevlar. While the Kevlar design offered certain advantages such as strength, it had inherent disadvantages. For example, typical cycle times of 30 days and 21 different manufacturing steps were to be expected. The process was labor intensive, material was expensive, and tooling was difficult to manufacture and had very limited life. Additionally, this process dictated that the ducts be tooled to the inner mold line which increased variability at installation.

In 1993, MDA installed the rotational molding equipment at its facility. Implementation of this technique and material required some engineering changes and concurrence in order to change the base material. MDA recognized that this is an emerging technology in the aerospace industry, with room for refinements and capability enhancement. Today, ducts are tooled to the outer mold line which reduces variability at installation, and five day part cycle times are the norm. In addition, process steps have been reduced from 21 to seven.

Total cost for project implementation was approximately \$334K, but MDA (St. Louis) has projected a five-year project savings of \$802K based on the redesign and reprocessing of only 17 different ducts. The projected savings, based on the quantity of 17 ducts, is in excess of \$30M over the life of one type of aircraft. The candidate part count is up from 17 to the current count of 90 ducts. Several additional part candidates are being considered for a redesign effort. This technology also lends itself to other part categories and should provide additional dollar savings.

Small/Small Disadvantaged Business Subcontracting Program

MDA (St. Louis) is aggressively improving its Small and Small Disadvantaged Business (S/SDB) Subcontracting Program. A recent analysis of SDBs' performance versus the total base shows that SDBs performed consistently in the area of on-time deliveries and quality acceptance. In addition, SDBs are being certified in the MDA (St. Louis) Supplier Certification Program. Currently, 50% of the MDA (St. Louis) preferred suppliers are S/SDBs.

MDA S/SDB program improvements include expanded support of the Historical Black College and Universities and the Minority Institutions (HBCU/MI) program and the Mentor-Protégé program. New initiatives for S/SDBs support breakout requirements, SB-only competitions, and business alliances. In addition, MDA (St. Louis) has established an HBCU/MI Partnership Program. The goals of this program are to increase the percentage of procurement from HBCUs; to increase the percentage of recruits from HBCUs; and to improve the technical quality of HBCU work. The partnership program includes the establishment of an HBCU/MI Advisory Board; the establishment of partnerships with HBCUs; the setting of a research and development budget goal for internal research and development, NBF, and corporate research and development; the funding of HBCU internships and cooperatives; the establishment of technical focal points to work with HBCU partners; and the development of the 1995-96 HBCU Strategic Plan.

MDA (St. Louis) is confident these efforts will be successful by the end of 1995 in meeting the government goal of 20% SB and 5% SDB subcontracts purchase orders. MDA (St. Louis) was at 22% SB and 7% SDB subcontract purchase order levels through March 1995.

Superplastic Forming/Diffusion Bonding

MDA (St. Louis) has successfully developed and used titanium Superplastic Forming (SPF) technology on fighter/attack aircraft. The company manufactures 180 different types of parts using the SPF single-sheet process and 13 different types of parts using the SPF/Diffusion Bonding (DB) process. SPF and SPF/DB of titanium at MDA (St. Louis) has resulted in cost savings of 20% to 50% and weight reductions of 10% to 20% when compared to conventional manufacturing methods.

MDA (St. Louis) has installed equipment (600-, 1000-, and 2000-ton presses) to perform SPF/DB to address manufacturing problems related to conventionally-fabricated aluminum and titanium structures. These structures contain numerous detailed parts and fasteners, and their parts with complex geometries are difficult to form accurately. Fabrication and

assembly costs are high, and reproducibility and interchangeability from lot to lot represent additional difficulties. In addition, honeycomb reinforced structures generate high fabrication costs, are difficult to repair, and experience high life cycle costs.

The F-15E Builtup Low Cost Advanced Titanium Structures Program provides a good example of the advantages of the SPF and SPF/DB processes. In this program, the number of aft fuselage parts was reduced from 772 to 46, and 10,000 fasteners were also eliminated. The load factor capability of the aircraft increased, weight was significantly reduced, and an additional 10 cubic feet of equipment space was gained.

MDA (St. Louis) is investigating using this process with aluminum alloys by purchasing a mature SPF-aluminum alloy technology base from Superform USA. The company has licensing agreements with Superform to include design and fabrication technology and rights to proprietary SPF-aluminum alloy materials. This capability provides the means to produce large and complex parts to replace conventional designs and fabrications, and the capability to fabricate complex geometries not possible with conventional techniques. The potential exists for significant reductions in the numbers of detail parts and fasteners with an associated potential for cost reduction of 10% to 60%.

Supplier Advisory Council

MDA (St. Louis) has recognized that procured components comprise almost two-thirds of the flyaway cost of a typical aircraft. As such, a number of processes and programs have been implemented to improve the MDA (St. Louis) supplier base. One such program is the Supplier Advisory Council. The Council's mission is to provide a leadership focus to issues that improve the affordability and effectiveness of MDA (St. Louis) suppliers, and to provide supplier insight to assist MDA in enhancing the competitive posture of its products.

The Council includes 21 members; 14 are executives from the certified supplier base. The other seven members are MDA executives, five of whom are permanent members of the Council, and all other members serve two-year terms. In the Council environment, executives of MDA (St. Louis) and its certified suppliers can proactively guide the improvement and deployment of the Supplier Management and Procurement Strategic Plan. It has also provided a forum for meaningful industry dialogue on strategic supplier issues.

The Council has been successful in identifying and resolving issues such as payment practices, supplier certification, standardization of contract terms and conditions, and suppliers incentives for affordability. These have all contributed to St. Louis' goal of being a preferred customer to

its suppliers, with world-class supplier management practices.

Supplier Conferences

MDA has established an infrastructure of support in its move toward partnership relationships with its suppliers. One key aspect of MDA's infrastructure is Supplier Conferences modeled on guidelines provided in the Keki Bhote book, *Strategic Supply Management*. MDA executive management is in full support of the partnering effort and advocates the supplier conferences.

There are three conference emphasis areas including Enterprise, Program-Specific, and Product Center-Specific. The purpose of these conferences is to improve the business relationship with the suppliers through a bi-directional communication path and provide recognition for their efforts and work in achieving preferred supplier status. The Enterprise Conference addresses accomplishments of the suppliers as a group and recognizes their achievements in the MDA-preferred supplier certification process. Program-Specific Conferences look at suppliers for a given program and discusses current program health and future marketing strategies with the specific suppliers. Finally, the Product Center-Specific conference focuses on those suppliers that provide general commodities for all MDA efforts such as forgings, castings, sheet metal, and machine parts.

All parties in these conferences benefit. For example, MDA wants to not only work with certified suppliers, but also wants to become a preferred customer for the suppliers and foster a continuing partnership. The incentive for the suppliers is in the prospects of future business opportunities to those who achieve the Certified Supplier status. And finally, MDA industry and government customers receive the highest quality products efficiently and effectively.

Supplier Performance Evaluation and Rating System

MDA (St. Louis) is enhancing SPEARS as part of its goal to implement world-class supplier management practices. Examples of this enhancement include continuing to reduce its "on time" delivery window and modifying SPEARS to reflect Direct Ship supplier performance.

SPEARS uses three metrics to evaluate and rate the suppliers—quality, on-time delivery, and a factor MDA (St. Louis) calls responsiveness. Responsiveness is a measure of hard-to-quantify factors such as response to problems, MDA (St. Louis) initiatives, or rework/repair turnaround times. The system calculates and reports supplier performance using established formulas, and rates the supplier against MDA's Gold, Silver, and Bronze preferred supplier

criteria. This information is provided in paper form on a quarterly basis to all suppliers. It is issued on a monthly basis for suppliers in the MDA (St. Louis) Preferred Supplier Certification program. In addition, MDA (St. Louis) is working with its suppliers to determine the feasibility of an on-line electronic system to allow suppliers access more detailed information on their quality performance.

Supplier Quality Improvement Board

The Supplier Quality Improvement Board (SQIB) is a multidisciplinary management team established by MDA (St. Louis) to review suppliers whose performance has declined below an acceptable level of quality, and to address concerns which require management review and corrective action (Figure 2-15). SQIB team members include procurement and quality assurance managers and representatives of various program disciplines such as supplier management, quality assurance, engineering, procurement, quality engineering, and program management. SQIB meetings are held to discuss supplier improvement, suspension, and disengagement issues.

There are currently five MDA (St. Louis) SQIB teams that meet on a rotating schedule – machine parts and sheet metal; castings, forgings, raw materials, and composites; purchased parts and pan stock; electro, hydraulic, mechanical, and major subs; and avionics, ground support equipment, and support equipment. Any supplier with a supplier performance measurement quality rating of less than 95% is monitored and reviewed by the SQIB. Actions that may

be taken by the SQIB include increasing material inspections, initiation of material review document responsibility amendments, conducting QA system or process surveys, issuing withholds, conducting process validation assessment or hardware audits, conducting supplier conferences, or disabling QA facility approvals in the purchasing system.

Since establishing the system in 1992, the SQIB has addressed 727 Unsatisfactory Supplier Reports, of which 563 have been closed out. At any given time, roughly 164 Unsatisfactory Supplier Reports and suppliers are under the SQIB review process. To date, 136 suppliers have been disabled in the purchasing system. The SQIB has been established as an open and objective forum to ensure timely and effective corrective action and has become a sound business practice that has resulted in a higher level of customer satisfaction.

Theodolite Coordinate Measuring Systems

MDA (St. Louis) has been using theodolite coordinate measurement systems since the mid-1980s to replace optical transits and tooling bars and to reduce manufacturing application and inspection times. The theodolite system is an optical measurement system for operators to map and send data points to a PC for storage and later use. The system uses two to four theodolite heads and a central computer to triangulate the position of data points for better coverage of the work envelope. Data can be collected at a rate of five points per minute using experienced operators.

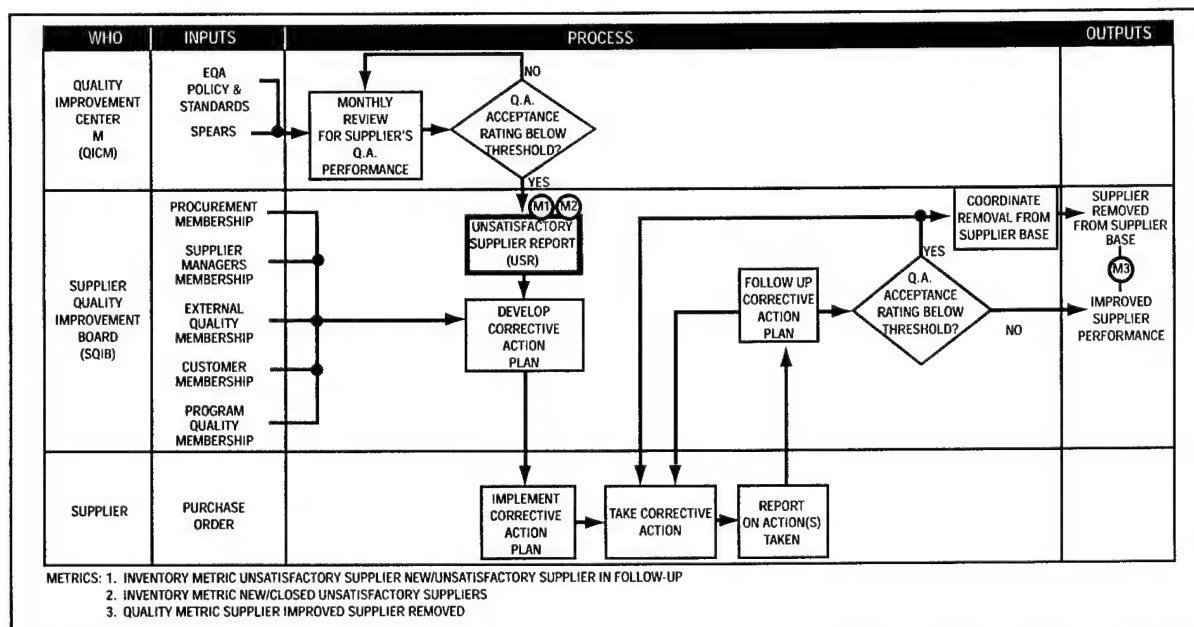


Figure 2-15. Supplier Quality Improvement Board Process Diagram

MDA (St. Louis) has greatly reduced set-up times on tools/fixtures and has reduced the need to move set-up and inspection equipment whenever a different area is being worked. Current inventory of these systems includes 19 four-headed theodolite systems and six two-headed theodolite systems. These existing systems are fully utilized and are essential in the collection of data for variability reduction and SPC. When down time occurs in the manufacturing area, the systems are occasionally moved to other sites and used for tool transfers or problem-solving applications.

When compared against optical tooling techniques, MDA (St. Louis) estimates that the implementation of this technology will result in a five-year average savings of over \$231K per year. Comparison between the F/A-18 C/D and the F/A-18 E/F manufacturing build-of-interface masters reveals an improvement of 5082 man hours, directly attributable to the application and use of theodolites in manufacturing. For the F/A-18 E/F program tool build, the MDA (St. Louis) tooling center is currently 195,000 hours under budget – also directly attributable to the use of theodolites. In the C-17 program, the MDA (St. Louis) tooling center was able to directly build associated tooling by using the digital theodolite readings of the tooling master at the McDonnell Douglas west coast facility, avoiding related costs and lost time in shipping the master.

Variability Reduction

A major element contributing to the cost of manufacture is the failure to understand and design for variation in component parts. MDA (St. Louis) has addressed this problem through the use of Integrated Product Definition (IPD) data sheets which query the way a part is dimensioned

and toleranced in relation to its functional use in a component. An MDA IPD team comprised of personnel from design, production, and assembly check parts for tooling requirements to ensure specified tolerances are realistic and not beyond the capabilities of manufacturing processes.

Two tools used in this variability reduction effort are geometric dimensioning and tolerancing, and design for assembly. Geometric dimensioning and tolerancing is a drawing language that communicates a part's functional requirements, defines common datums, controls tooling and assembly interfaces, and provides uniform international interpretation. Elimination of excessive tolerances results in better product performance and reduced cost of assembly. Design for assembly focuses on part count reduction by eliminating unnecessary parts and combining others into one. The application of these methods has reduced the number of parts on the F/A-18 E/F by 33% over the previous C/D model.

Logistics/Management

Benchmarking Process

The MDA (St. Louis) benchmarking program builds on techniques used by companies such as Xerox, IBM, AT&T, Texas Instruments, and Motorola. It is a systematic and continuous measurement process for collecting benchmarks on superior processes, products, and services from other organizations. The process determines the specific actions for enhanced performance and integrates the results into the MDA (St. Louis) Continuous Process Improvement Process.

A five-step approach (Figure 2-16) is applied in this MDA effort. Before a study is conducted, process capabilities,

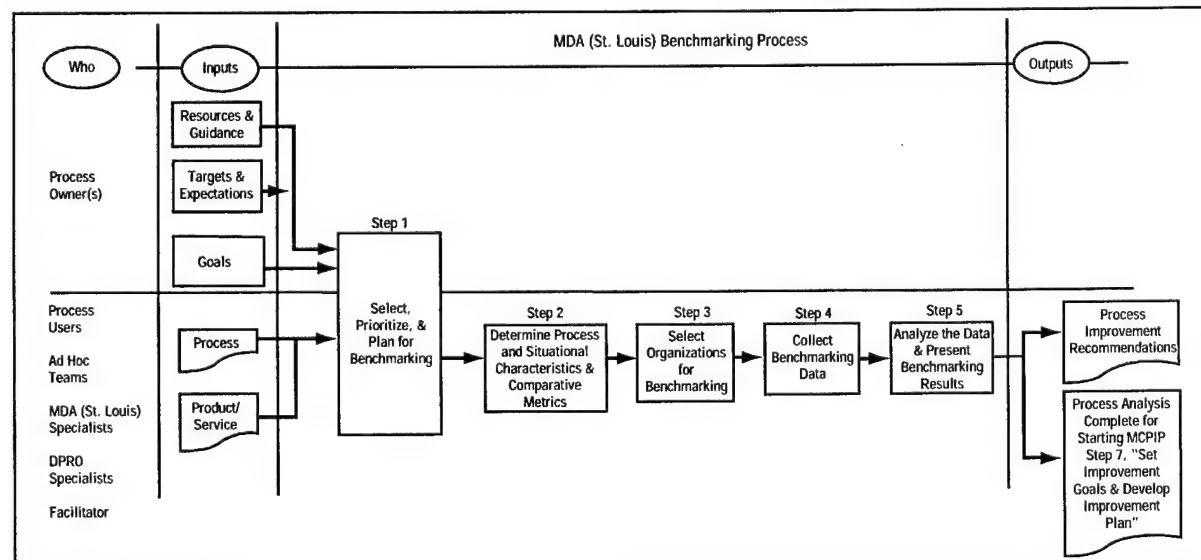


Figure 2-16. The Five Step Benchmarking Process

expectations, goals, and metrics are established and obvious problems are addressed. The company is highly selective in its benchmarking program. For example, in determining what to benchmark, MDA (St. Louis) focuses on critical or high priority processes, products, or services that impact customer satisfaction and provide a competitive advantage.

The process is disciplined and uncomplicated. Easy-to-use templates provide guidance for selecting and prioritizing benchmarking topics, performing benchmarking readiness assessments, and other key activities. Hierarchy models of the types of benchmarking and data collection methods are applied, and personnel are trained in the advantages and disadvantages of each method (Figure 2-17).

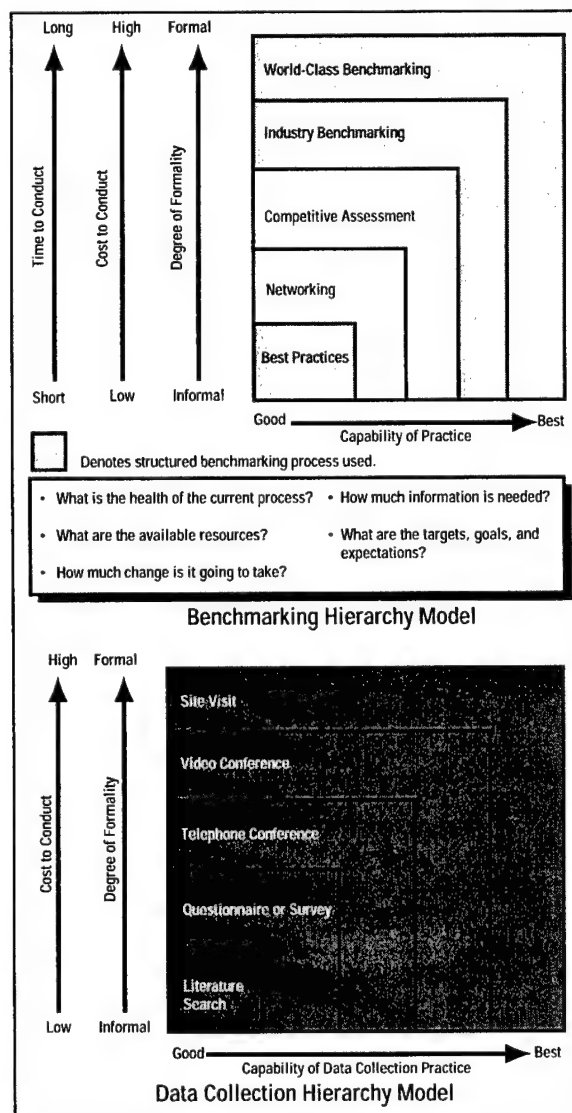


Figure 2-17. Benchmarking Process Features

Benchmarking champions at the company and corporate levels provide consistency and leadership in continuing to develop and improve the benchmarking process.

Training development for benchmarking includes looking at the best training programs in industry. Three classes are available at MDA (St. Louis)—a one-day course, a two-hour overview, and the Voluntary Improvement Program. The classes are available to all MDA (St. Louis) employees and are also offered to suppliers and external customers at no charge. All senior management at the vice-president and director levels have received the two-hour overview. Government representatives have also been trained, and the courses are in demand by suppliers.

The benchmarking process is very effective in obtaining participation from benchmarking partners. One indication of this is a response rate of consistently greater than 50% for benchmarking questionnaires sent to other companies—more than double the national average response rate. Future improvements to the process include development of an internal database of best practices, corporate-wide process integration, and continuous improvement.

CALS/CITIS

MDA (St. Louis) combined the CALS goal and CITIS capability into a single environment which supports the effective execution of Integrated Product Development. This is accomplished through immediate availability of high quality information and real-time collaboration in the Integrated Product Development work process. MDA integrated the CALS goal of enabling effective generation, management, and exchange of digital data in support of weapon systems, and the CITIS capability of providing electronic access to and/or delivery of contractual requirements to users to provide a mission for the Integrated Product Development/CALS environment. That mission is to support electronic and real-time collaboration of the right information to the right personnel at the right time and in the right form, thereby creating a true concurrent engineering environment.

The charter from the MDA (St. Louis) perspective is to provide capabilities to manage program information with controlled access and delivery internally and for customers, subcontractors, and suppliers in compliance with the electronic commerce standards. The goal is to continue to implement an Integrated Product Development/CALS environment within the 1995-1997 time frame. This includes significant Integrated Product Development performance improvements through timely provisioning of digital information, electronic interaction with customers and suppliers, and immediate access by teams and management to required information. The collaborative creation and use of electronic documents constitute the key factor. The need for

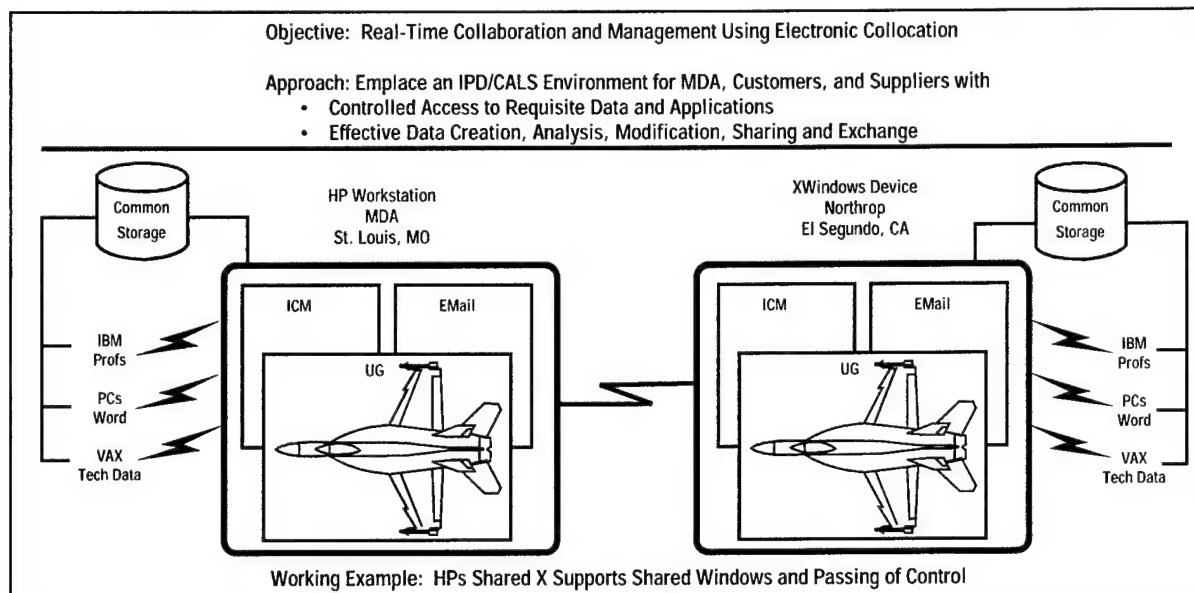


Figure 2-18. CALS/CITIS Benefits

a robust location, with retrieval and packaging of data through a common user interface is a critical element of the Integrated Product Development/CALS environment.

MDA (St. Louis) has a structured approach to the implementation of Integrated Product Development/CALS. It has a Strategic Plan, first issued in February 1994 and updated annually to define implementation priorities. The strategic plan outlines drivers, vision, elements of the environment, and the business focus. A three-year tactical plan is also created for 1995-1997 and is program/product-focused with deliverables, milestones, tasks, and resources.

A significant objective of Integrated Product Development/CALS is the culture change it requires for its successful execution because the implementation of an Integrated Product Development/CALS environment supports the virtual enterprise. Although company elements are physically dispersed, they are electronically connected. Digital information is readily available to authorized personnel and can be easily shared and exchanged.

MDA (St. Louis) has seen significant benefits through the use of the CALS/IPD environment such as enhanced affordability through first-time quality and reduced cycle times. The F/A-18 E/F automated data transfer with Northrop (Figure 2-18) achieved a savings of 90% labor and 98% cycle time. Real-time design reviews were conducted electronically, achieving a savings of 90% in time and eliminating all travel. A total of cost savings of 98% was achieved by MDA and suppliers using the CITIS node.

Enterprise Process Model - the Eight Key Processes

As part of its process-based management program, MDA (St. Louis) is using a Model Structure (Figure 2-19) to ensure complete and systematic coverage. The highest level (Level 0) is divided into eight key processes which each have a senior executive as an owner. These eight process include Asset Management, Business, Human Resource Management and Services, Integrated Business Planning and Management, Integrated Product Definition, Post Delivery Support, Production Flow, and Supplier Management and Procurement.

These processes encompass all programs and projects undertaken by the company. Programs such as the F/A-18 aircraft program represent a business unit, and the eight key processes impact the success of that program. Under each Level 0 process are a number of Level 1 processes such as

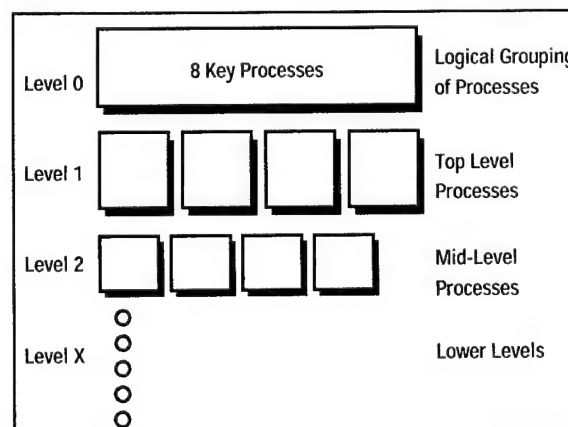


Figure 2-19. Process Model Structure

Manage Physical Assets, Fabricate Tools and Parts, Assemble and Test Product, Assure Product Quality, all of which come under the Production Flow Level 0 process. There are also Level 2 processes for each of the Level 1 processes with levels cascading to Level 5. To date, all Level 2 processes have been documented using the process model methodology, and metrics have been developed for analyzing performance.

The key to successful application of the eight processes is to choose Levels 1 and 2 processes critical for focused improvement of the organization. MDA (St. Louis) has developed a Process Manual and a Process-Based Management sourcebook that are used to ensure consistent application of the methodology, and to provide guidance for selection of truly critical processes from among many possible processes. All management reporting systems now reflect this process-based management philosophy, and it is one of the key elements in MDA's (St. Louis) efforts to produce high-quality products at an affordable cost.

Foreman Development Process

In mid-1993, MDA (St. Louis) developed a program to train new foremen and improve the performance of current ones, as a structured approach for promoting bargaining unit employees to foreman positions did not exist, and newly-promoted foremen were given little substantial supervisory training.

A director-level task force was assembled to lead development of a closed-loop system for selecting and training both new and existing foremen. A foreman development process was created to guide the training and evaluation program creation. An instructional development steering committee included representatives from across the MDA (St. Louis) product and support elements. Subject matter experts were also gathered from across the organization to contribute to development of a comprehensive foreman skills matrix. In the current foreman selection process, employees volunteer for the program, and these candidates then take the Adult Basic Education Test and participate in a behavioral event interview. Successful candidates subsequently enter the training program.

The instructional program is organized into four levels:

- Introductory (Off-site training overview and discussion of foreman's roles and responsibilities),
- Basic Skills (Communications, coaching, time management, problem solving),
- Basic Shop Floor Skills (Labor relations, human resources, policies, schedule, quality, and available support), and
- On-the-Job (Coach assists a new foreman on the shop floor).

The training program covers 29 subject areas needed for developing competent foremen. Each area has a knowledge test for post-training use. The curriculum developed is intensive and comprehensive. The first class which was recently completed for 37 students was well received, and pre-test/post-test scores demonstrated a significant increase in foreman skills and knowledge across all instruction modules.

The MDA (St. Louis) effort expended for selecting, training, and evaluating foremen represents a wise investment with significant future pay-off. The comprehensive training process will continue to provide MDA (St. Louis) with highly-skilled and trained foremen.

Hornet Quality Award

MDA (St. Louis) established the Hornet Quality Award (HQA) as its preeminent form of team recognition for F/A-18 aircraft program. In 1992, MDA was challenged to develop the highest quality F/A-18 aircraft to meet the U.S. Navy requirements and expectations. The company accepted the challenge and implemented the annual award in 1993 as an incentive to the F/A-18 teams. This prestigious award was designed to encourage the teams to produce quality products on time, and recognizes teams instead of individuals or managers. The award acknowledges outstanding team successes and encourages team empowerment throughout the workforce.

The HQA examines and distinguishes team performance in five strategic quality objective categories of leadership, customers, people, supplies, and processes. Teams are encouraged to apply in one of these five categories. Evaluation teams of corporate vice presidents and directors select three finalists in each of the categories. After additional review and interviews, a winning team is selected in each category. Runners-up are debriefed during the selection process.

Team winners in the five categories are recognized at an HQA Reception and ceremony held in October (Quality Month) of each year. Spouses and guests are invited, and each team receives a banner and plaque for display in the work area. Team photos are taken, and all team members receive a *Teaming for Quality* desk award.

The Hornet Quality Award program has been very successful in fostering F/A-18 team spirit, cooperation, performance, and productivity. Twenty-five applications for the award were received in 1993, and 39 were evaluated in 1994. This award has produced positive team results in the areas of quality, cost, schedules, and customer satisfaction as envisioned when MDA accepted the challenge in 1992.

The *Hornet Wire*

At MDA (St. Louis), the *Hornet Wire*, an F/A-18 newsletter distributed daily through electronic mail, was created by the F/A-18 Leadership Team to address a problem with its communication process. Previously, other MDA publications were not distributed often enough to keep current with the growing program, or their focus was too wide to cover F/A-18 specific issues. The Leadership Team wanted a medium that could respond rapidly to new information, provide a means for open communication, and was F/A-18-specific. A daily electronic newsletter filled this gap in the communication process.

The *Hornet Wire* operates under a unique set of guidelines. It is the only publication at MDA (St. Louis) that does not undergo an executive review before it is published which is attributable to the rapid turnaround time and the high level of trust MDA (St. Louis) management has in the newspaper's editors. Information published in the *Hornet Wire* is non-sensitive and suitable for wide distribution. The finalized newsletter is transmitted to readers through PROFS (MDA's electronic mail system), VAX computer, and the Integrated Management Information and Control System.

Information for the newsletter is obtained from various sources. For example, the editor attends daily stand-up meetings. Guidelines state that if a comment is made at the daily stand-up meeting, and the editor of the newsletter is not specifically instructed to disregard it, the information can be printed. Conference calls with the Washington, DC F/A-18 office provide another source of information. The *Hornet Wire* editor also receives different publications, newspapers from different parts of the country, rewards and recognition data provided by HR, and news items from MDA (St. Louis) employees.

Regular features in the newsletter include stock information about defense industry, flight/delivery status, leadership team reports, the Navy program manager's reports, new business updates, press clips, information from the Fleet, recognition programs, upcoming events, visits, MDA (St. Louis) press releases, public service announcements, and the "quote of the day."

The *Hornet Wire* initiated distribution in January 1992 to 1100 E-mail accounts. The distribution list as of 1 April 1995 had increased to 2500 known E-mail accounts. Although the distribution originated in St. Louis, it has today expanded to other MDA (St. Louis) program components, functional organizations, field offices, foreign offices in Europe and Asia, MDA (St. Louis) suppliers, and the U.S. Navy.

"Wire watching" has become popular among its readers with new E-mail addresses being added daily. The *Hornet Wire* has established itself as the most credible and timely source of information of F/A-18 news. Over the past three years, it has demonstrated that electronic media has the

ability to enhance communications and information flow. Other MDC programs have established similar news services, using the *Hornet Wire* as a model.

Inside Compensation Newsletter

MDA (St. Louis) has introduced an Inside Compensation Newsletter to inform employees of policy and/or philosophy changes in the merit review process. This newsletter is a one-page publication published by Human Resources (HR) to communicate merit review issues, and address issues in the corporation compensation program such as changes in the performance appraisal process, the merit review budget and pay philosophy, and adjustments in the labor rate changes. It supports the communication process and provides employees information to better understand the merit review process and general compensation practices.

The newsletter is published on an as-needed basis and has different distributions depending on the issues addressed. For example, one issue included a memo published to management that discussed new job codes for all employees. Another issue outlined the Merit Review and Organizational Performance Bonus and was routed to supervisory and salaried employees. The January 1995 newsletter included MDA (St. Louis) rate range changes effective in March and also addressed market labor rates for the St. Louis area.

The publication process begins with a draft prepared by the HR Compensation Staff and reviewed by HR Management. Modifications are made, followed by a review and approval by the Executive Business Council. Once approved, the newsletter is published and distributed to the appropriate personnel.

The Inside Compensation Newsletter provides a communication capability on important personnel issues. This effort has led to a better understanding and awareness of the merit compensation process and its elements for all MDA personnel.

Integrated Management Information and Control System

The Integrated Management Information and Control System (IMICS) at MDA (St. Louis) is an electronic bulletin board which displays program health indicators such as cost, schedule, and technical risk. The information is formatted to show absolute qualification, historical trend, and compliance. The degree of compliance with program requirements is indicated using a red-yellow-green system.

This comprehensive system provides performance measurement and risk assessment for program management at all levels and is used in all major MDA (St. Louis)

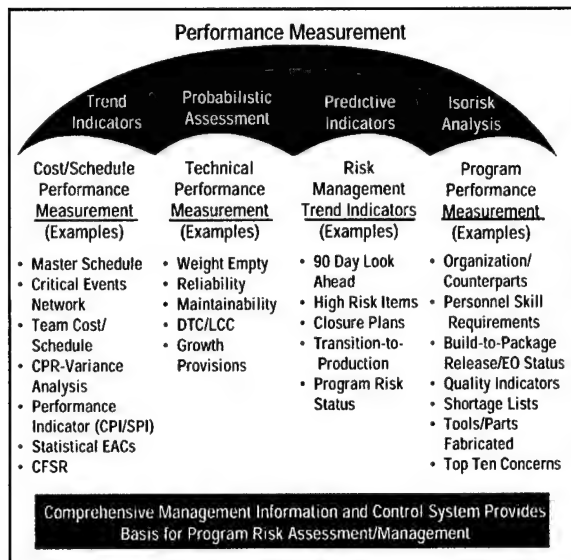


Figure 2-20. IMICS

programs. Figure 2-20 presents the four indicator categories tracked by the system and examples of each. The goal of the system is to capture a broad range of program data and status information and provide the trend analysis necessary to give the company and customer a sound basis for continuous program health assessment.

Development of the system was motivated by U.S. Navy concerns expressed in 1991 about MDA's (St. Louis) capability as an organization to manage – particularly cost, schedule, risk, and people. The Navy challenged the company prior to awarding the F/A-18 E/F EMD contract to provide proof that it would properly manage the program. The problem was to transform the massive amounts of data

that existed into timely and useful management information. MDA (St. Louis) put IMICS in its F/A-18 E/F Management Proposal which described what information would be shown, how the information would be auditable, who would see it, how it would be accessed, and other key aspects of the system. The Navy was satisfied and awarded the EMD contract to MDA (St. Louis) in June 1992. With this award, the company implemented a new management information culture. Because of its enormous success and effectiveness, IMICS has been deployed across the enterprise and made available to subcontractors and customers.

IMICS draws on all existing systems for performance information, including technical performance, cost, schedule, and work packages. Figure 2-21 shows the system flow from major subsystems throughout the company. Information is input by cost account managers and team leaders to the appropriate systems which process the data and generate charts. IMICS collates the charts and data and makes them accessible in bulletin board format through a menu system. The information is available internally at all levels from the cost account manager to company president and externally to customers and major subcontractors.

MDA maintains that IMICS has been a primary contributor for keeping the F/A-18 E/F EMD program on schedule, below cost, and technically sound. The IMICS team won the highest excellence awards at the company and corporate levels in 1992. The Navy recognized the system as a major strength of the EMD contract, and related to MDA that the EMD program is the first of over 260 research and development programs since 1975 to have any management reserve after critical design review.

IMICS has been instrumental in introducing a new culture within the company involving multidisciplinary, integrated product development teams, disciplined processes, independent program analysis, systems engineering, risk management, total team accountability, and honest, open communication. It has helped significantly improve many key management processes. As a "single source" database, IMICS has become an essential tool for the company, customers, and suppliers.

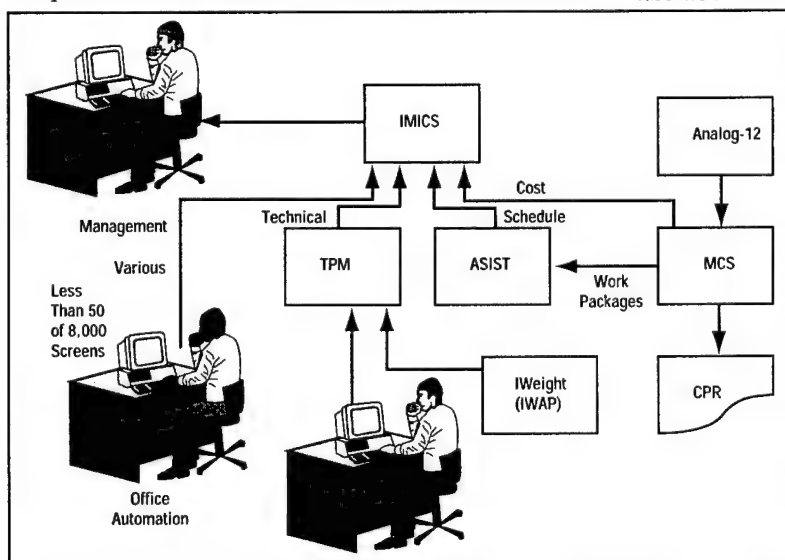


Figure 2-21. IMICS System Flow

Integrated Product Development Certification

MDA's (St. Louis) Integrated Product Development (IPD) Certification is a tool for providing a structured methodology to assess and improve the current state of IPD implementation. This process began

in 1992 with the development of the IPD Compliance Matrix that outlined ten IPD principles and an associated rating scheme for current projects.

A survey, conducted in 1993 of employees representing six projects, yielded average scores for each of the ten IPD principles that helped identify each of the project's potential best practices and areas for possible improvement. The questionnaire used in the IPD certification continued to evolve and presently consists of approximately 165 questions that focus on and provide measurements of:

- goals, plans, technical performance;
- policies, procedures, and training;
- cost and schedule accountability;
- supplier involvement;
- customer involvement;
- teams and concurrent product/processes;
- configuration management;
- common data and tools;
- integrated scheduling; and
- process based management.

The IDP process is supported by a certification toolkit that consists of behavior charts for each principle, the interview questionnaire, a scoring structure, standard analysis and validation approaches, and templates for feedback reporting. The questionnaire has been administered to a large number of employees from each of the major projects and has highlighted areas of excellence and clearly defined areas for improvement. These programs are currently de-

veloping and working out improvement plans based on certification findings.

Integrated Product Definition Process

MDA (St. Louis) created its IPD program in 1992 to identify all activities and personnel required to deliver a product to internal customers and suppliers. This program represented a major shift in how project teams were identified. When MDA (St. Louis) made this management change, it contacted companies that were known to be making similar changes, and benchmarked with Texas Instruments, Ford, Martin Marietta, Northrop, and Vought.

To help implement the new management changes, MDA (St. Louis) created Multidiscipline Integrated Product Teams for a skill-based organization. One significant change was including personnel from manufacturing (such as tool design engineers) to participate on the project team. They were collocated with design engineers and the other up-front disciplines. This move helped to initiate MDA's concurrent engineering effort (Figure 2-22).

These teams are cross-functional teams and formed with the specific purpose of delivering a specific product or service to the customer. The members are selected for their skills to complement other team members. Each team is expected to design for manufacturability and ease of assembly. One project team, responsible for updating an aircraft design, has been able to reduce the number of parts required by 33% on schedule, on cost, and has eliminated 11,000 defects per aircraft.

To prepare personnel to participate on these project teams, MDA (St. Louis) instituted 14 hours of required training per individual. Team leaders received 90 hours of classroom training on issues that included responsibilities, accountabilities, and authority. The members of each team were committed to a common purpose, performance goals, and approach for which they held themselves mutually accountable.

Integrated Product Definition Quality Measures

The use of IPD Quality Measures at MDA (St. Louis) provides on-line management tools that allow managers and team members to monitor performance to established goals for IPD critical processes and tasks. The tools were developed in response to a 1992 management request for specific performance measures. Key processes and metrics were identified and presented to management in early March 1992.

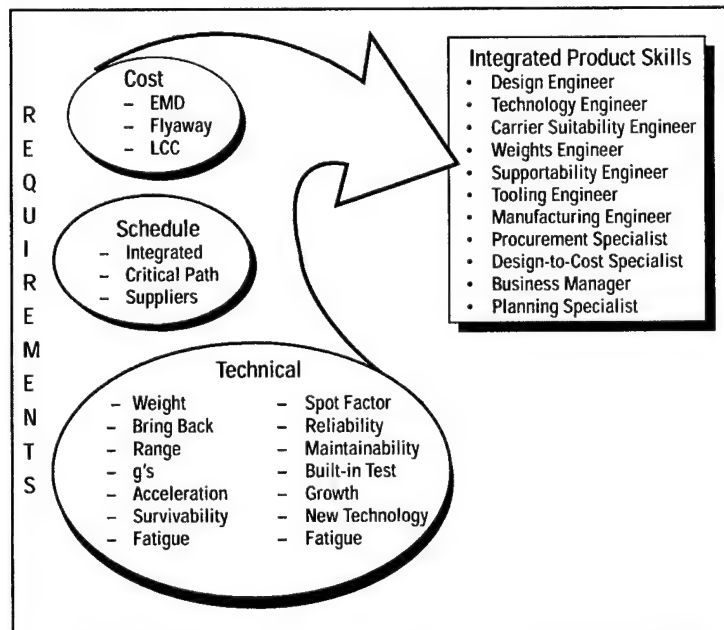


Figure 2-22. Multidisciplined Integrated Product Team Considerations

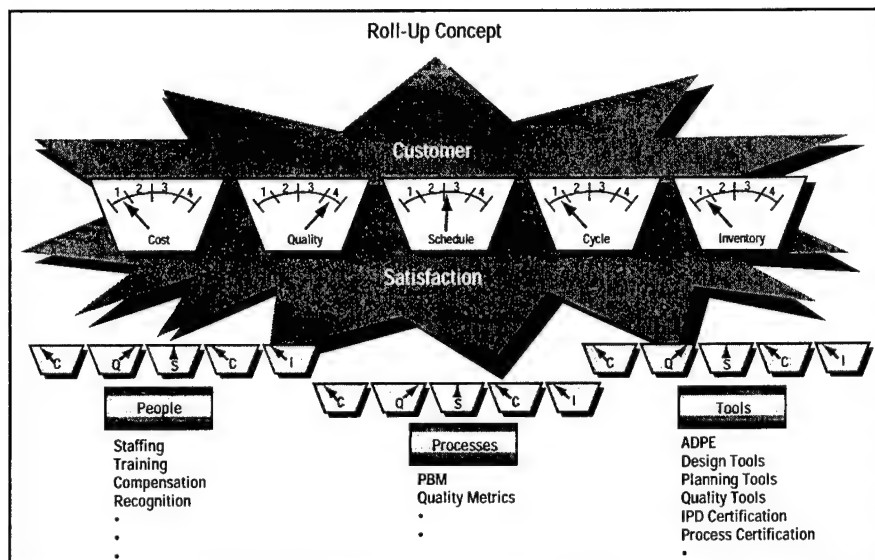


Figure 2-23. Performance Measures Process

The Engineering Quality Metrics Implementation Plan was developed to document measures and identify which new measures were to be developed. IPD measures can now be rolled up for senior management (Figure 2-23) and are provided on-line and, in some categories, updated weekly. Access to some customers has also been implemented with success. There are quarterly executive management and monthly director-level reviews performed using these metrics which are adjusted as necessary to improve useability. These metrics have evolved into measures that now are among the most essential elements of the management decision-making process.

Performance measures provide indicators of overall performance, conform to continuous improvement standards, and provide direction to both workers and management. They also help to define future goals and communicate them to the performing teams, establish overall performance vision for IPD, and are convenient, timely, and graphically interpretable.

Integrated Training Plan

In 1992, MDA initiated a concerted training planning effort, resulting in a structured training process plan across the total organization. The previous training process was fragmented and did not focus on the true needs of the organization or the individual team members. The streamlined training program now provides an integrated link to strategic business objectives and goals, is leveled across the organization, meets corporate and individual needs, and balances training needs with budget realities.

A senior-executive Education and Training Horizontal Integration Team was chartered to integrate training across the organization by addressing training needs, curricula, business plans, and budgets. The 1995 Integrated Training Plan, for example, was developed using the training planning process and defined 280 courses available to MDA personnel in distinct categories including a broad selection of continuing education courses called the Voluntary Improvement Program.

The team updates and expands the Integrated Training Plan annually as needed by organizational requirements, strategic

goals, and individual needs. MDA has a viable, well-documented process that meets the training requirements of the organization and its individuals, and is balanced with affordability considerations.

Logistics Support Analysis

MDA (St. Louis) has made significant changes to its Logistics Support Analysis (LSA) process since 1992. This LSA analytical engineering effort brings together design and support concepts during the systems engineering process. LSA processes within MDA (St. Louis) have been systematically enhanced (Figure 2-24) to include all product analysis pertinent to supporting the customer and products in the field. LSA is performed as an integrated product team activity and takes into consideration both life cycle cost and overall affordability. The changes that MDA (St. Louis) instituted have centered on personnel skills requirement and an integrated system environment. As a result of the LSA enhancement, MDA (St. Louis) has been recognized by both the Price-Waterhouse Benchmark Project 2000 and the Aerospace Industries Association's benchmark project.

MDA (St. Louis) used the SLIC-2B, a time-phased approach to migrate from four dissimilar LSA systems to a single integrated one. This system serves as the single database for logistics data and delivery, and represents a key factor in MDA's successful LSA enhancement. Also, as a result of an MDA (St. Louis) initiative on personnel LSA skills, multiskilled logisticians perform life cycle system support. Tasks are performed in less time and with higher level of quality.

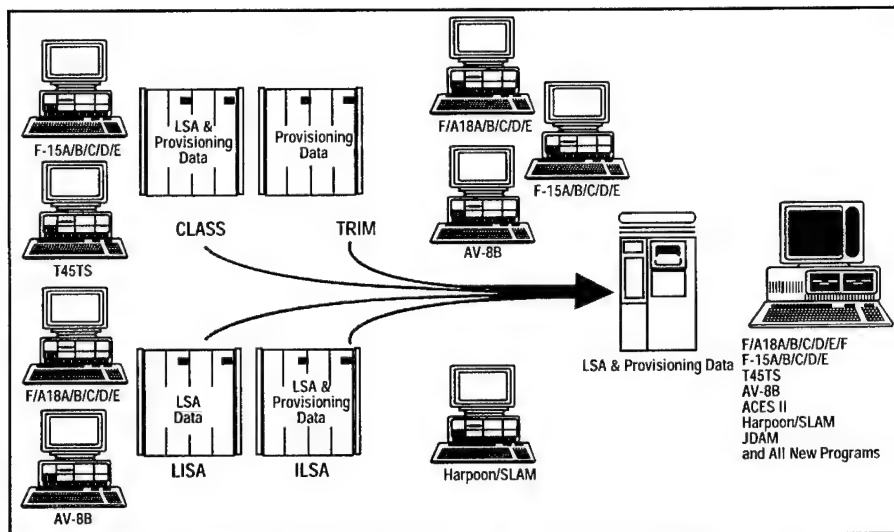


Figure 2-24. Logistics Support Analysis Migration Strategy

MDA (St. Louis) participated with 41 aerospace companies in a common benchmark effort developed, deployed, and graded by Price Waterhouse. In "Lessons Learned," MDA (St. Louis) LSA received six of six possible points and was rated by Price Waterhouse as Best-of-Class. The MDA (St. Louis) Logistics Engineers represented on the Integrated Product Teams received five of six possible points and were among the best. The Trade-off Studies/Failure modes used in systems design also received five of six possible points.

The Aerospace Industries Association similarly conducted a benchmark project for LSA with 250 companies, 56 of which were defense-related. The Association identified MDA (St. Louis) LSA strengths in four areas such as the disciplined implementation of MIL-STD-1388 1A/2A/2B. MDA (St. Louis) was considered the best in this area. The second was alternative methods to deploy LSA, and a third area was consistently meeting or exceeding customer requirements. The fourth category was in excellent automated deployment of MIL-STD requirements.

Logistics Support Analysis Record

MDA (St. Louis) Logistics Support Analysis Records (LSARs) document data from across all ILS functional areas. These LSARs, captured in an electronic database, provide an excellent example of the CALS concept of "create/store once, use many times." The relational design of the LSAR data was designed to facilitate integration and to encourage the use of ad-hoc queries for accessing different data files. The LSAR provides

an integrated product development/CALS environment that supports real-time access to information with a single point, on-line access to the logistics database. This access is provided through the use of the CALS/Contractor Integrated Technical Information Service (CITIS) node using a point-to-point methodology (Figure 2-25).

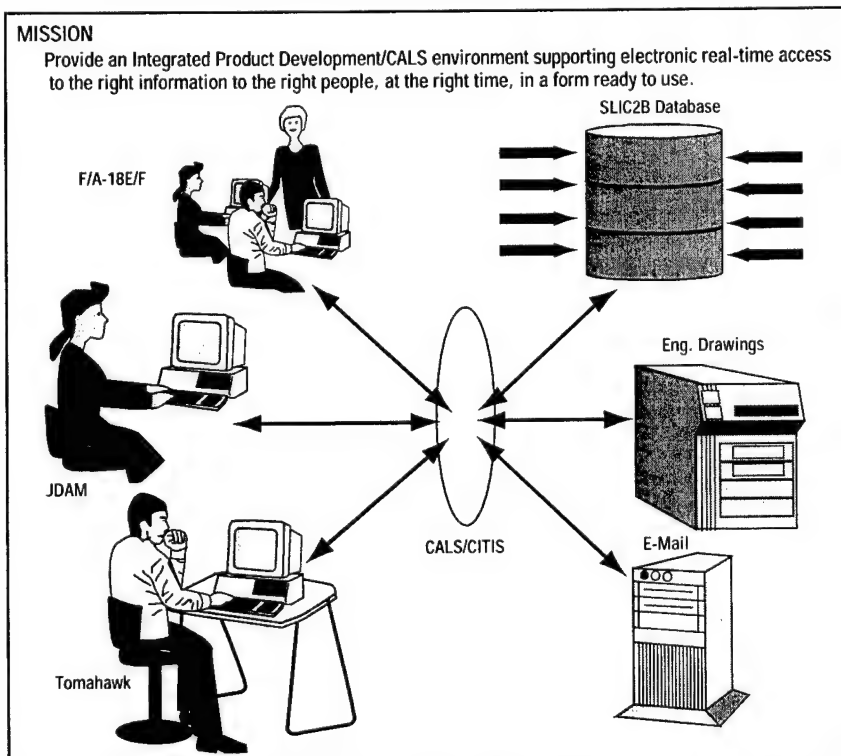


Figure 2-25. CALS/CITIS Current Direction

Prior to 1993, major programs distributed information in various databases and individual islands of information. This did not allow internal or external customers easy access to data; there was no on-line capability; the only means to obtain information was through hard copy; and there was no single point of access for LSAR data.

The logistics database now serves as a single source of information for all LSARs. Any data file can be generated through ad hoc queries as well as any discrete LSAR requested by the customer. MDA (St. Louis) LSA has been extended to allow for Provisioning Technical Documentation and to tightly integrate the LSA/LSAR process to both the present Technical Manuals and the development process and emerging Interactive Technical Manual process.

The logistics database contains the three elements of SLIC-2B applications, 1388-2B LSAR, and Extension tables, and shares common processes, data, and applications. Two major aircraft programs currently use this logistics database for data storage. The LSAR allows data exchange, requirements roll-down, and support for various data delivery options (dependent on customer contractual requirements). Customers and/or vendors can interact with the MDA (St. Louis) logistics database in several ways such as FTP, electronic data interchange, and from floppy disks.

People Strategic Plan - 1995

The MDA (St. Louis) People Strategic Plan provides integration of enterprise-wide, people-related issues and creates a linkage to the MDA Strategic Business Plan. This HR goal is to effectively implement multi-sourced data to establish a coordinated, non-duplicative employee plan.

The plan defines strategies for closing the gap between the company's current and future state, identifies plans executing those strategies, and ensures funds are allocated to carry out the plans. After the corporation develops the visions and strategic corporate objectives, the strategic planning process requires three months of planning and

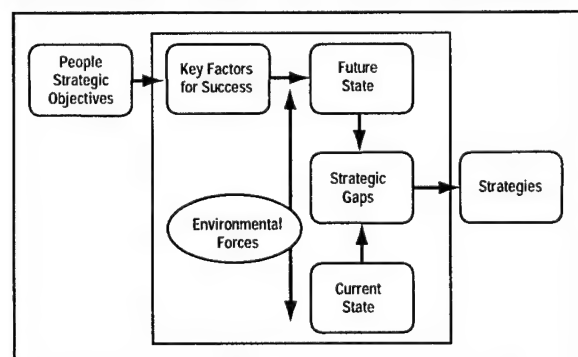


Figure 2-26. Environmental Assessment Methodology

analysis, for a total of nine months for implementation during any fiscal year.

Applying the corporate people vision, MDA (St. Louis) formulates objectives aligned with the company's business objectives. Figure 2-26 illustrates MDA's (St. Louis) environmental assessment process which includes several internal measures and surveys, as well as several external sources through benchmarking with other companies. The key to the MDA process is its thoroughness and carefully thought-out methodology which applies a "Gap Analysis" that concentrates on closing gaps between the current state and the future (desired) state.

Performance Cost and Schedule Process

MDA (St. Louis) developed a process-based management approach to cost and schedule control systems and merged two division manuals on cost/schedule control system criteria into one Process Management Guide. It was one of the first process-based guides in industry and was developed in less than a year by a multidisciplinary team, incorporating benchmarking results and customer inputs.

A performance management team was established with representatives from every business unit to review and approve all system description changes, and communicate the cost and cost process changes. This team, which was established as the owner of the system, worked to support the deployment of the system across the company by identifying process sponsors and owners, and ensuring that the cost and schedule processes were consistent with the new Process Management Guide. The performance management team also established metrics and goals for the new process, and worked to involve the customer representatives as active participants.

The Process Management Guide has been successfully applied in the F/A-18 E/F program. It has documented a consistent set of high-level guidelines for the cost and schedule processes, has documented the processes for improvements in support of company affordability initiatives, and has improved the involvement of the customer and employees in the cost and schedule process.

Presenteeism Program

A program was implemented at MDA (St. Louis) in 1984 as an incentive to encourage and recognize those employees who achieve perfect attendance. Full-time employees are recognized through three separate award opportunities including annual recognition awards, awards for multiple year continuous attendance, and drawing awards.

Awards can be anything from a certificate and a pin for one year perfect attendance to \$175 award for perfect

attendance above five years. After five consecutive years of perfect attendance, there is a bonus of \$325 in addition to the \$175 annual award. At ten consecutive years, MDA (St. Louis) awards the employee \$675 plus the \$175 annual award, as well as 2 additional days of paid vacation. The drawing awards take place twice a year. Employees with six months of perfect attendance place their names in a "hat" for one of 63 prizes that range from three awards of a \$4000 bonus plus 5 additional days of vacation, to fifty awards of \$175 each.

This program has been successful for over ten years. Improvement has been steady from a 17.5% perfect attendance record in 1984 to 56.4% in 1994. These statistics translate into real productivity improvement per dollar expended.

Problem Identification, Escalation, and Resolution Process

MDA's (St. Louis) Problem Identification, Escalation, and Resolution (PIER) process helps manage the life-cycle of problems that occur within a product team's area of responsibility, authority, and accountability. Initiated in 1991, the PIER process is a valuable aid in communicating problems and resolutions to the customer.

When potential problems arise, the appropriate RAA team first creates a problem reporting document on a dedicated PIER process computer system. The team then uses program standardized criteria to consider safety, operations, maintainability, integrated logistics, support, and production issues, enabling them to classify the problem into one of five priority categories. Based on the assigned priority classification, the problem is elevated to the appropriate level of visibility within the project management structure. Next, the RAA Team and other subject matter experts develop a resolution to the problem, implement the corrective action, verify problem resolution, and iteratively reach closure. The automated system keeps an on-going status of all activities related to problem resolution and ultimately represents a permanent record of the problem and the resolution process. It is easy to use, accommodates several concurrent users in the database, ensures that nothing is lost or forgotten, and can handle thousands of open problems. There are several types of problem reports that can be generated using this process including aircraft discrepancy reports, field service reports, engineering investigations, hazardous material reports, and Check Six reports.

Numerous advantages have been recognized as a result of the PIER process, including the reduction/elimination of the adverse impacts of problems, and timeliness in problem identification and resolution.

Process Assessment Guide

All critical and high priority processes at MDA (St. Louis) are required to have a completed process assessment. In support of this requirement, the Process Assessment Guide has been developed by MDA (St. Louis) to help users assess, evaluate, and analyze process maturity. In practice, the guide is used by the process team – which typically consists of the process owner, users, customers, and suppliers – to understand and evaluate process maturity. The Process Assessment Guide presents 15 process criteria for users to determine if each is categorized as Uncertain, Repeatable, Effective, Efficient, or Premier. The team then uses the feedback results to identify opportunities for improvement to the process and also iteratively track the progress of process improvements.

As a generic tool the guide contains:

- an overview of the development and application of the Process Assessment Guide;
- the Assessment Guide which contains a summary of the criteria and one-page questionnaire for each criteria;
- feedback forms used to deliver the results of the assessment to the process owner and the process team; and
- a glossary of key terms and definitions, and a sample process assessment.

Results include improvements in customer satisfaction, financial performance, quality products/services, schedule, and cost and value.

Retrofit Configuration System

The Retrofit Configuration System (RCS) at MDA (St. Louis) incorporates digital data for aircraft life cycle support and provides digital information that supports product functionality and configuration control (Figure 2-27). The RCS contains relational database files and support graphic files that can be transferred to CD-ROM for read-only capability, and facilitates automated graphics retrieval from the relational database.

Originally established in response to a need from the Israeli Air Force, RCS provides an in-country configuration management system on CD-ROM that eliminates the paper trail to research aircraft information. MDA (St. Louis) is using this system internally to maintain configuration management on aircraft retrofitted at MDA (St. Louis). Data is stored by part number and broken down to the drawing number. MDA (St. Louis) also developed the capability for the user to retrieve technical drawings from the database and view them on a PC.

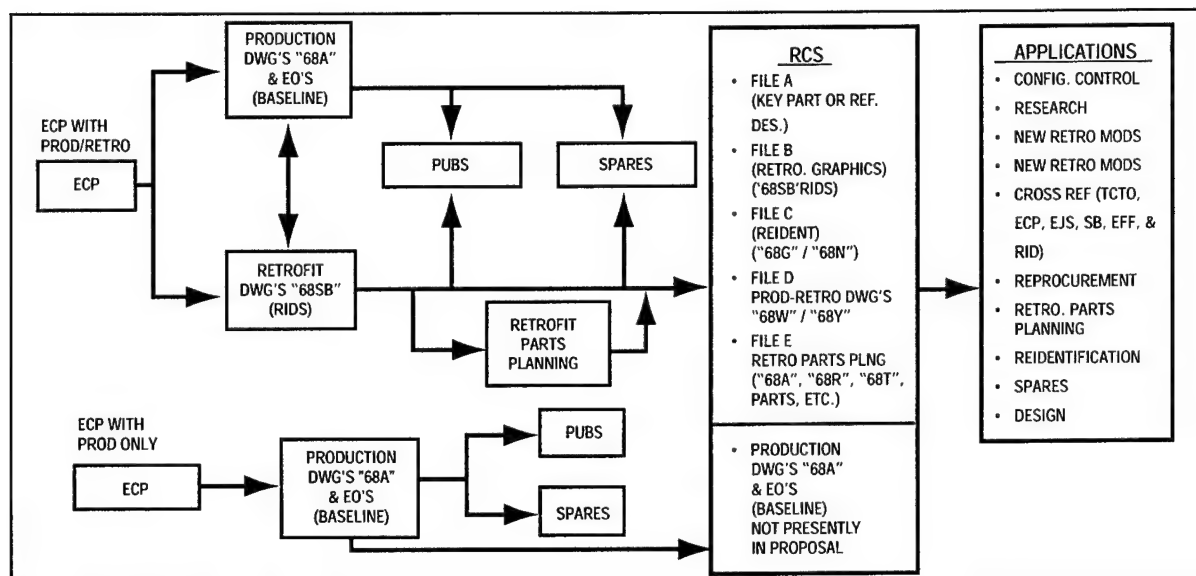


Figure 2-27. Retrofit Configuration System Logistics Relationship and Applications

The production engineering drawings are used to define the baseline of the system. The post-production engineering drawings with retrofit are incorporated into the relational database, creating a new baseline for the system. Aircraft parts are broken down into mechanical and electrical parts. The RCS is designed for query in several fields such as engineering change proposals, service bulletins, and time compliance technical orders. The ability to cross reference among pertinent data such as time compliance technical orders, and modification number is a valuable capability for MDA (St. Louis).

The relational database allows rapid access to updated electrical and mechanical configurations, and support equipment modifications. RCS is the only automated source to research fielded aircraft configurations and related modifications. A benefit of the relational database is that it stores graphic records of the aircraft configurations with incorporated retrofit modifications. It also stores parts planning information for parts added during retrofit. This system also provides traceability for all spares re-identification and interchangeable items without spares. The system can also accommodate future aircraft modifications.

Time is a critical factor related to equipment maintainability. RCS has the capability to maintain a complete history of the modifications done to a particular series of aircraft. This translates directly to a time reduction in design research or aircraft audits. The benefit that RCS provides the user is the ability to track the re-identification of spared parts and interchangeable parts without spares for a specific aircraft or modification. The RCS baseline drawings and re-identification records aid in accessing replacement equipment requirements of battle-damaged aircraft in the

field. This system provides accountability of all post-delivery changes, design criteria, and continuous baseline updates to the aircraft configuration.

Strategy-to-Technology Process

MDA (St. Louis) has developed a Strategy-to-Technology (STT) Planning Process (Figure 2-28) system to aid in program requirements definition. The STT system,

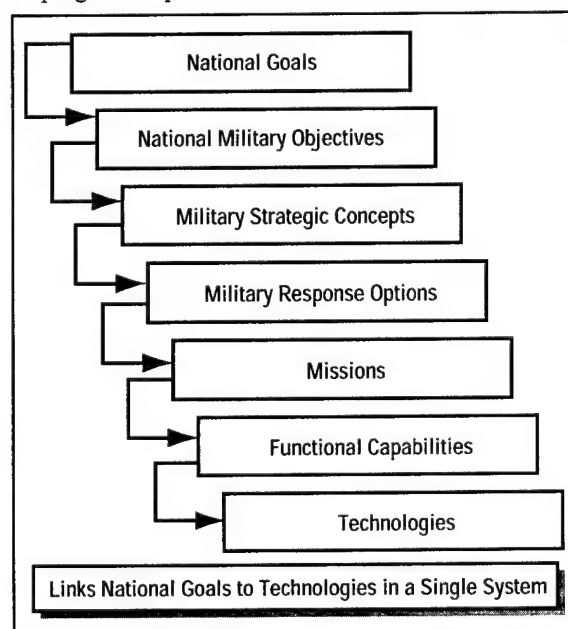


Figure 2-28. Strategy-to-Technology Process

designed by modifying the QFD methodology, helps users determine where technology investments should be spent to improve their impact while facing declining defense budgets. Previously, MDA (St. Louis) had been developing technology to support products only, with no plan toward meeting future military objectives. The STT system provides MDA (St. Louis) with the ability to focus technology efforts on future system requirements.

The process works by using a QFD-type methodology for each level of analysis. The analysis moves through seven levels such as National Goals, Military Strategy and Missions, working down to Technologies. Each level of analysis incorporates Importance Values, permits weighting of External Factors/Competing Priorities, and permits sensitivity analysis by varying Importance Values. At each level of analysis, the output of the previous level serves as input into the level below. This process continues until the bottom level – in this case technology – is reached. The STT system incorporates sensitivity to defense budget levels, alternative U.S. futures, and alternative futures of world regions.

The QFD/STT approach is applicable when there are multiple users or customers; user requirements are not quantifiable; there are conflicting user requirements; there are multiple feasible solutions; the solutions are not yet quantified; the solutions conflict with each other; and, there are multiple disciplines involved.

Using the QFD/STT process has many benefits. It provides a detailed approach to solving complex problems that have no obvious solution or means of reaching a solution. It provides well-documented results and a documented process for reaching those results. When this approach was applied to determine where MDA (St. Louis) should be investing technology research investments, it resulted in re-focused research to meet the needs identified through the analysis. This approach has proven to be flexible enough to be used for many other applications. MDA (St. Louis) has been able to apply this methodology to solve both internal and external problems.

Supplier Best Practices

MDA (St. Louis) recognizes that many of its suppliers have attained levels of proficiency in processes and techniques which are efficient and effective, some which may have application at MDA or be used to improve the overall supplier base. Teams perform Business Process Assessments as part of MDA's Preferred Supplier Certification process and observe many of these processes and collect the information. No proprietary or confidential company information is collected, only that information which can be used to improve MDA (St. Louis) and which its suppliers are willing to provide and share. These practices and processes are observed and validated first-hand by an assessment team.

Before data is collected, the guidelines are discussed with the supplier to determine any objections to documentation of the process for benchmarking and/or identifying the firm to other MDA (St. Louis) suppliers as a possible contact for benchmarking. Participation is strictly voluntary and no pressure is applied to the supplier. Processes receiving a high score by the MDA (St. Louis) assessment teams are considered as opportunities for formal benchmarking. Unique processes may be considered if they have application external to the firm being reviewed. Processes scoring slightly lower but viewed as outstanding may also be considered for benchmarking. These often include recent processes which appear to have very good results but are not yet proven.

Approximately 16 supplier best practices have been documented to date, and interest and participation is growing. The program offers a unique and effective way to improve the capabilities of MDA (St. Louis) and also offer improvement opportunities to its supplier base.

Supplier Management and Proficiency Program

MDA (St. Louis) established a Supplier Management Proficiency Program as a training program to ensure the disciplined and consistent application of proven supplier management techniques. MDA (St. Louis) recognized that 60-65% of the flyaway costs of its products are procured from suppliers, and a study commissioned by the company convinced MDA that such a supplier program was necessary. The program was initiated in 1993, and a basic curriculum was completed by the end of that year. The Supplier Management Awareness Training was one of the first courses developed and offered at MDA (St. Louis).

The supplier management training program focuses on professionals whose backgrounds are in engineering procurement and/or business, with seven to ten years of experience. Eight basic skills are required – supplier management, business management and procurement, supplier systems, communication, leadership, customer focus, continual improvement, and multidiscipline.

The supplier management curriculum includes 58 courses that total over 400 hours of course work. An employee achieves "certification" after 186 hours of course work. Of this total, 101 hours must be in the areas of skill development and core competency, and 85 hours in elective areas.

Total Quality Management System and Process-Based Management

In the early 1990s, MDA (St. Louis) developed and deployed Process-Based Management (PBM) as a centerpiece for meeting TQM and PROCAS initiatives. PBM

includes all enterprise-wide activities and actions for managing, maintaining, and improving the manufacturing of MDA products. This program is deployed systematically throughout the company in support of the following four principal goals.

1. Maintain control of processes.
2. Understand the process capabilities and how well they are performing.
3. Improve process performance.
4. Predict process outcomes and trigger corrective action.

MDA (St. Louis) executes this PBM through focus areas of an Enterprise Process Model, Enterprise Coordination, Approaches, General Improvement, Enterprise documentation, Common Tools, and Enterprise Measures. The Enterprise Process model is the foundation of the PBM strategy by defining the hierarchy of all processes and establishing the framework for how MDA (St. Louis) conducts business. It provides a structure to prioritize improvement efforts by identifying critical processes. In support of Enterprise Coordination, a Strategic Quality Council is responsible for implementing PBM at MDA (St. Louis) and coordinates improvement strategies and activities with other MDA councils.

This program is deployed systematically throughout the company and is based on an Enterprise Process Model which defines the framework for how MDA (St. Louis) does business. It prioritizes improvement efforts by identifying critical processes. Responsibility for implementing PBM rests with the Strategic Quality Council which coor-

dinates improvement strategies and activities with other councils and boards. Proven strategies and methods are used to improve processes and are supported throughout the enterprise with documentation to provide common tools, techniques, and structures. These facilitate learning, interfacing, and process improvement. Enterprise level measurement systems are used to gain an understanding of the health and performance of the company from an overall perspective.

Continuous improvement requires a disciplined and focused process to address gaps that must be filled between the current state of operations and a desired end state. At MDA (St. Louis), this effort supported the process-based management concept and the effective use of teams. Many tools have been developed to help implement this philosophy. Regular assessments and reports are produced to help management in its decision-making and budget allocation process.

The key elements that make MDA's (St. Louis) total quality management system work are the thoroughness and rigor with which it is pursued and the dedication of management in using the information provided by TQM assessment tools in making business decisions. The internal self-assessment uses the Malcolm Baldrige criteria. Each company under the MDA (St. Louis) umbrella prepares a yearly report on its quality efforts and achievements.

A team of eight examiners evaluates each report and conducts a site visit. A real-time feedback report is presented to each company's senior management, and this feedback is used by senior management to focus the improvement efforts.

Section 3

Information

Design/Test

Advanced Design for Quality Avionics Systems/Design for Quality Aerospace Systems

MDA (St. Louis) developed the Advanced Design for Quality Avionics Systems (ADQAS) and Design for Quality Aerospace Systems (DQAS) processes to provide discipline and repeatability to the product development process from the development/acquisition phases through operations and support. These processes emphasize use of Integrated Product Development and Concurrent Engineering to produce a supportable product that meets performance expectations and cost.

ADQAS/DQAS processes emphasize disciplined, repeatable design processes for a balanced product. These processes integrate System Engineering, Tolerances and Margins, Key Characteristics, Variability Reduction, Simulation Tools, Design for Producibility, Integrity Concepts, and Test Verticality. As a part of the Integrated Development Process, the ASQAS and DQAS guide the Integrated Program Plan, Design Engineering, Manufacturing, Test Equipment, Quality, Reliability and Maintainability, and Supportability of a product until all exit criteria have been met. For example, on one radar program, the project team has been able to develop a new design that decreased the number of processes for fabrication from 35 to five, and the number of drawings from 52 to three. Cycle time was reduced from 24 weeks to seven weeks, and the cost was 33% of what it was to produce the old design. During integration testing, the program experienced one failure in 600 hours, ten times better than in the past.

With the introduction of ASQAS/DQAS processes, MDA (St. Louis) has added discipline and repeatability to new designs. These new processes have provided cost, schedule, and quality savings on programs where they have been utilized.

Automated Mass Properties System

MDA (St. Louis) began developing its Automated Mass Properties System (AMPS) in 1986 for weight engineering calculations to provide mass property information quickly and accurately. This information was previously hand calculated or obtained from engineering estimates using mechanical drawings and scales.

AMPS is an interactive system that weight engineers can use to calculate surface areas and volumes rapidly, calculate area properties, calculate volume properties, manipulate the calculated properties, store properties and geometry definitions, and transmit properties to input files for database input. It uses wire frame model data from a Unigraphics CAD system, and provides an interface between a mass properties database and Unigraphics. The database is being converted to Oracle, which is based on the UNIX operating system, to work more efficiently with the UNIX-based Unigraphics CAD system. Once the mass properties data is calculated, it is stored with the Unigraphics model.

MDA (St. Louis) has seen many benefits from developing and using AMPS. Manpower requirements for mass property calculations have been reduced by up to 50%. The accuracy of calculations has increased significantly compared to manual calculations. An error of 0.2% was recorded on 3500 pounds of parts with the maximum error for any single part recorded at less than 7%.

Avionics Engineering Process Handbook

MDA (St. Louis) developed an Avionics Engineering Process Handbook which details a plan for developing avionic systems. Released in January 1993, it includes the process that specifies what needs to be done, in what order, and by what work groups. It is also a reference document that details products, internal and external review requirements, and the necessary coordination among work groups. The handbook consists of an overview and three appendices on Concept Exploration and Development, Demonstration and Validation, and Engineering and Manufacturing Development.

The handbook has been developed top-down based on the DOD acquisition life cycle including the DOD 5000 series acquisition document requirements. The overview describes the handbook, DOD process, baselines, and general documentation. For each DOD phase, the program model and the avionics engineering process are described. The overview is used for understanding the process and for top-level planning. Figure 3-1 shows the relationships during the acquisition process phases.

The appendices are used to detail the avionics engineering process for each DOD phase and for guidance during detailed planning and program execution. Each appendix contains the program model, process diagram, product flows, product tables, and activity descriptions.

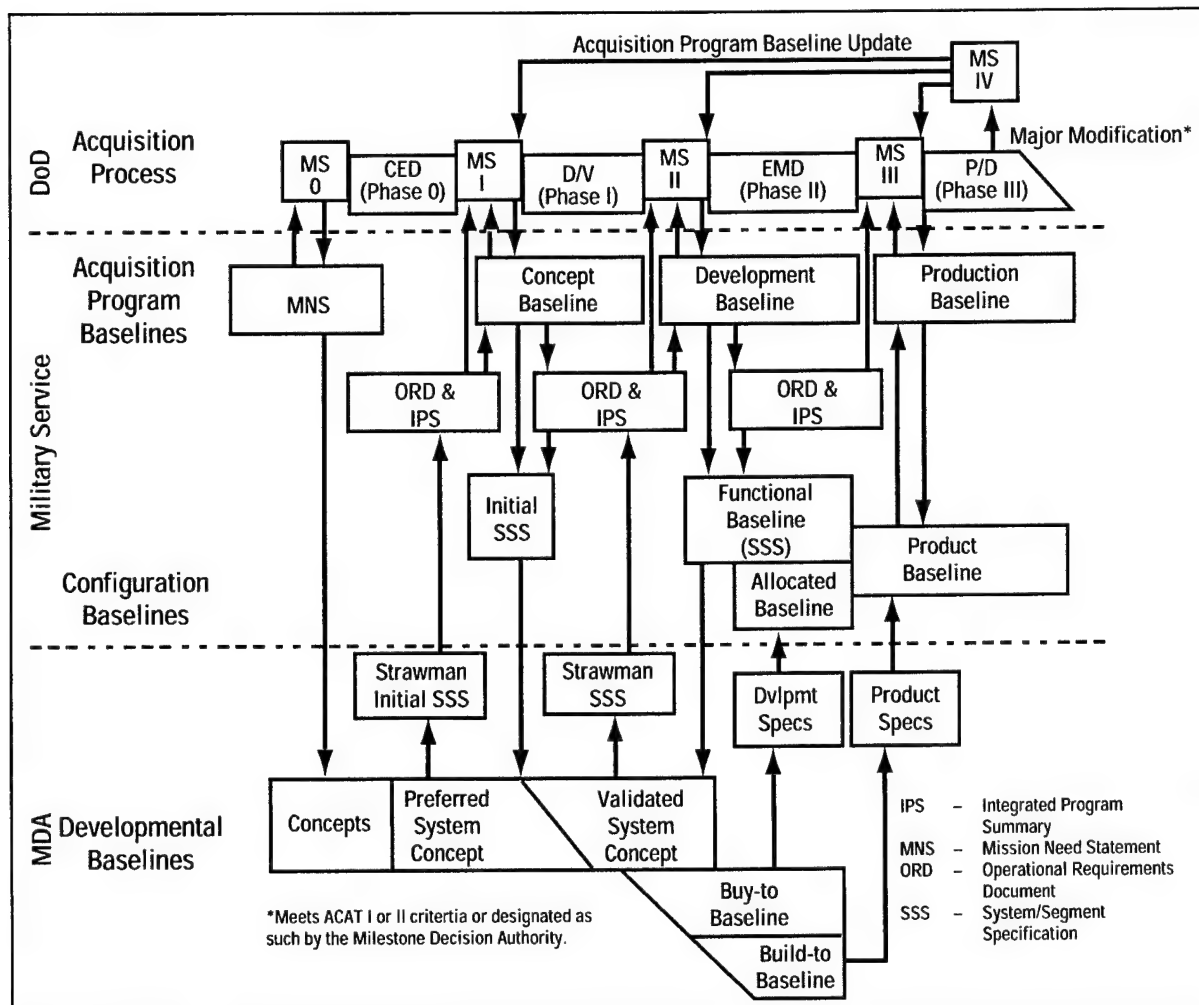


Figure 3-1. Baseline Relationships

The program model identifies milestones and milestone objectives for each DOD phase, and it forms the basis for the detailed process. The process diagram follows the program model, identifies activities for the avionics system and subsystem work groups, and shows the relationships between the work groups. There are two types of product flows, product flow diagrams and product flow relationships. The product flows identify products for each work group and their relationships to the program model and to each other. The product tables define the content and level of detail for each product at each milestone. The activity descriptions provide detailed descriptions of each effort for each activity. The activity descriptions use Entry criteria, Task description, Validation requirements, and Exit criteria.

The process can be tailored for any program definition. The entire process is documented in such a way that it is directly relatable to fulfilling System Engineering Program

Planning. It covers all DOD phases leading to production as well as major upgrades. The handbook has been used for AX avionics program planning, proprietary programs, other departments, and for development of the Integrated Product Development Life Cycle Deliverables Handbook.

Baseline Comparison System

MDA's (St. Louis) Baseline Comparison System (BCS) is a set of current operational systems/equipment, or a composite set of current operational systems/equipment, which most closely represents the design, operational, and support characteristics of a proposed system/equipment under development. The BCS defines a quantitative performance baseline and a problem set from which performance projections for systems/equipment can be made. Development of the BCS data requires the participation of multiple functional areas. Multiple BCS's may be developed to

support each alternative considered during concept exploration or during trade-off analysis.

The BCS provides a convenient methodology to aggregate data. Once the data is accumulated, the BCS can be used as a starting point for any subsequent study or analysis. The BCS ensures that everyone is using the same set of data when considering alternatives. It contains the system/equipment requirements, description, operating environment, functional block diagram, and preliminary maintenance concept. BCS's are evaluated to determine the best possible match to the critical characteristics of the system/equipment. Any similarities, differences, risks, and assumptions are documented. Reliability and maintainability, qualitative and quantitative data, readiness values, testability values, environmental hazards, hazardous materials, health hazards, ILS resource requirements, operational and support cost data, qualitative supportability problems, applicable lessons learned, and supportability, cost and readiness drivers are also documented.

Once the data is developed, it is adjusted to reflect the operational environment. The adjusted data is then used as a point of departure for the development of design requirements and projections for the system/equipment baseline.

The BCS is a well organized system that helps ensure that all of the proper considerations and trade-offs have been evaluated in a proposed system or equipment under development, minimizing surprises later in the development cycle.

Design for Manufacturing and Assembly

MDA (St. Louis) has developed a process called Design for Manufacturing and Assembly (DFMA) to reduce inventory and work-in-progress, which together represent 51% of MDA's total assets. DFMA is an integrated process encompassing Integrated Product Development, Manufacturing Support, and Production Operations teams. The process concentrates on Integrated Product Development data sheets which represent assembly, tooling, and tolerance information and are associated with the product's Unigraphics master model.

DFMA includes a production flow analysis (Figure 3-2) in which assembly se-

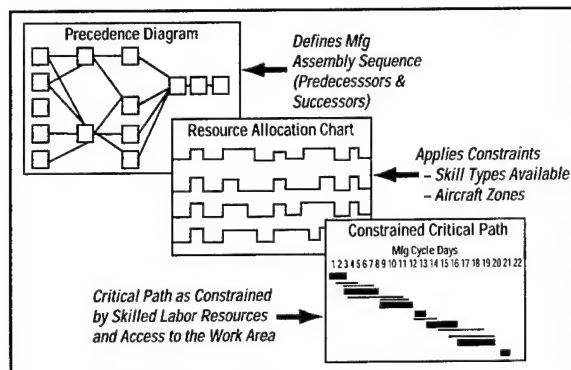


Figure 3-2. Production Flow Analysis

quences are captured in precedence diagrams. Personnel and production resources are then allocated, and a resource-constrained critical path for assembly is generated with the help of MDA-developed Compass software. Potential assembly problems due to part tolerance variation can be analyzed using Variation Simulation Analysis (Figure 3-3), a commercially available manufacturing statistical simulation and analysis package. This analysis can then be used to identify causes of variation and to indicate potential areas where tolerances might be adjusted to minimize defects without compromising quality.

DFMA has been used on the C-17 landing gear pod program to reduce the number of different fastener types, reduce the overall part count, and simplify the assembly process. This effort has resulted in a shorter assembly cycle time and reduced cost.

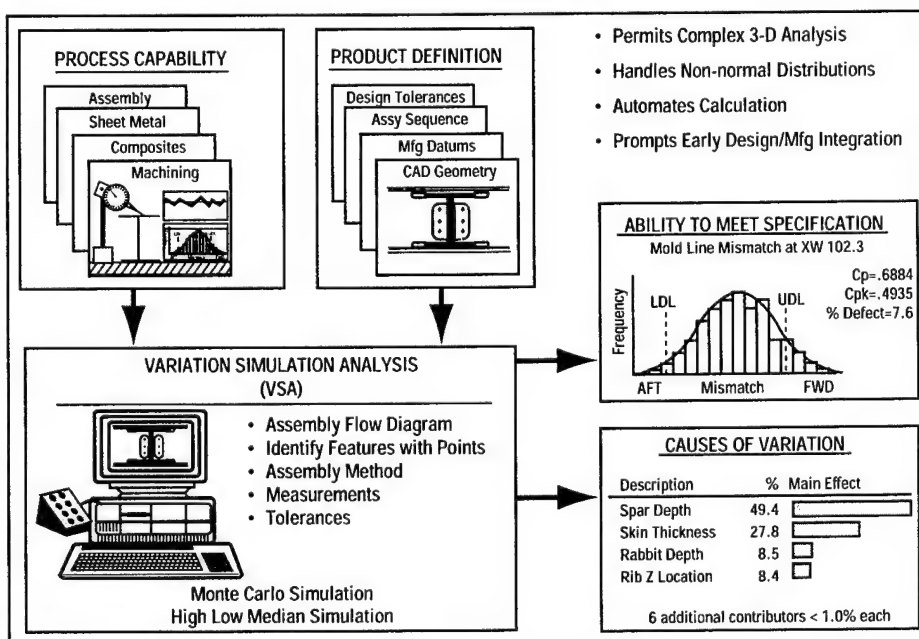


Figure 3-3. Variation Simulation Analysis

Electronic Development Process

MDA (St. Louis) has initiated an Electronic Development Process that divides the three-dimensional electronic mock-up of an aircraft into discrete zones or volumes. This process uses digital models of details, subassemblies and subsystems to create a model of a total aircraft platform. Although the Electronic Development Process does not produce a releasable document or drawing, it does provide the hierarchical structure and procedures to allow collection of in-work and released parts into zones. This program, in support of MDA's Integrated Product Development Process, has produced positive results in post-release change activity with such programs as the TAV8 aircraft program.

The zone models are assigned to individual "zone captains" who are responsible for the physical systems integration within individual zones and between adjacent zones. The zone captains manage allocation of space within individual zones; coordinate with product definition teams; and ensure form, fit, function, clearance, reliability, supportability and maintainability. Coordinating the efforts of these zone captains is an Electronic Development Process manager who organizes zone management activity, establishes procedures and policies for digital product models, and schedules and manages regular zone reviews.

MDA (St. Louis) anticipates applying this approach with solid modeling of systems (zones) to support new capabilities. If a zone is broken into smaller subzones that are labeled with the system occupying the space, engineers can locate the product models in the Unigraphics system more easily for a particular area in the zone. Using subzone data, it may also be possible to do battle damage analysis with the solid modeling system.

Engineering/Manufacturing Tracking System

The Engineering/Manufacturing Tracking System (E/MTS) provides MDA (St. Louis) a capability to develop unique, multidivisional schedules for each activity between release of an engineering drawing through loading the part onto the jig fixture. The E/MTS replaces the old process of using a simple algorithm that differentiates only machine part span times from sheet metal span times with a more sophisticated approach that considers multiple constraints such as part type and size, material selection and complexity diversification. The new approach leads to a consistent process for development of the item release schedule by applying a new practice of Forward Scheduling instead of the Back Dating for estimates of part scheduling. The new practice requires that manufacturing personnel participate in the engineering design process which follows and implements Integrated Product and Process Development.

E/MTS provides an accurate date on the work order, accurate WIP, estimates for prioritizing assembly planning, and work schedules for detail planning. This capability enhances the development of a precedence chart that depicts the overall flow of the product assembly, and for which the production line's detailed requirements and constraints are established. The E/MTS is integrated with other applications such as the Large Order Assembly Planning System, Common Bill of Material, Engineering Automated Release and Record System, and Fabrication Tracking and Management System. This integration provides a mutual set of information common to all the application software. The data is also updated by the production centers that use the E/MTS to track the actual schedule. This update provides vital information on part production status and actual information that is used for a baseline for future estimates.

Benefits of this system are being realized by the F/A-18 E/F, T-45 and AV-8 production lines and the C-17 pod redesign line. Use of the E/MTS has improved the process of estimating man-hour/cycle of manufacturing activities, improved fabrication cycle estimates, provided consistent estimated fabrication cycle span for all changes, and assisted in timely make-or-buy decisions.

Feature-Based Machining

MDA (St. Louis) is developing software for Unigraphics that explores the impact of feature-based machining on processes and business cases. A feature is a stereotyped aspect of a part that has useful functions. There are design features, engineering features and machining features. Feature recognition can lead to automated process planning or NC program generation. The MDA (St. Louis) software for Unigraphics feature based machining attempts to identify machining features from Unigraphics geometry for generation of NC code. Feature Based Machining requires:

- Definitions of features
- Software recognition technology
- Definition of logical interferences such as fixtures
- Feature intersections
- Database of tooling, materials, costs

Successful technical demonstrations will lead to evaluation of the business case which may lead to process changes. Potential process changes are:

- Add production verification of the solid model to reduce cycle time
- Cost estimates based on manufacturing features and best NC practices
- Reduce the cycle time to create NC instructions
- Use cutter logic, tool sheets, operations lists and diagrams with subcontractors

There is a significant amount of work remaining, but successful completion of these process changes would improve productivity and competitiveness.

Lessons Learned/Supportability Design Baseline

MDA (St. Louis) developed a lessons-learned database system in response to a Navy requirement that all lessons learned must be reviewed and applied to new products. The system contains lessons learned from MDA (St. Louis), the Navy, and Air Force.

The lessons-learned system is a VAX program using an Oracle database which has the capability to maintain, retrieve, and print lessons learned. The system is completely menu driven for easy use. Lessons can be retrieved in several ways such as by keyword, by lesson number, or by text string. New lessons learned can easily be added to the database after approval by the steering committee.

MDA (St. Louis) has applied the information contained in the lessons-learned system to specific products using another VAX program and Oracle database. This program is called Supportability Design Base Line and uses a matrix form to identify lessons learned, product specifications, MIL-SPECs, and fleet-recommended improvements that apply to a particular product, then provides a management tool to track product requirements and trace them back to their source. The system also provides real-time status of requirements by listing them in one of three categories – Rejected, Incorporated, or Deferred. It also tracks the reason for the status.

Programming Coordinate Measuring Machines

MDA (St. Louis) uses an off-line programming procedure to create inspection data points for checking machined parts using a ZEISS Coordinate Measuring Machine (CMM). A programmer familiar with the APT programming language can quickly generate a program that automates the inspection of the machined parts features using the CMM.

The program for the CMM is created off-line in APT language on a Unigraphics workstation. The intermediate moves necessary to avoid collisions with the part being inspected are included in the program at that time. Once the

program is verified, it can be downloaded to the CMM for use when the part is ready for inspection.

The benefits of programming off-line include efficient use of the CMM by eliminating using manual programming methods. This allows the operator to devote efforts to part inspection rather than evaluating and interpreting engineering drawings associated with the part. It also provides a consistent inspection method regardless of personnel performing the inspection. Another benefit is detecting drawing and model deficiencies before the actual part inspection. Currently, in addition to Dimensional Inspection, off-line programs are able to evaluate cylindricity, straightness, roundness and flatness of the machined parts inspected using the ZEISS CMM. In the manual mode, the CMM is capable of evaluating all geometric dimensioning and tolerancing functions.

Ready-to-Fabricate Process

MDA's (St. Louis) Ready-to-Fabricate Process is an organized and integrated development process for structural equipment that begins with the description of conceptual layouts. This process is carried through to the design data, fabrication/assembly work instructions, fabrication/assembly tooling data, quality assurance instructions, and parts/materials procurement instructions. Serial processes such as collecting requirements, implementing the design, releasing the drawings, planning the manufacturing process, determining requirements and inventory, completing tool definition, and developing tool drawings can now be administered concurrently through integrated development teams.

This approach (Figure 3-4) avoids the costly and lengthy result of developing products twice. Explicit exit criteria are

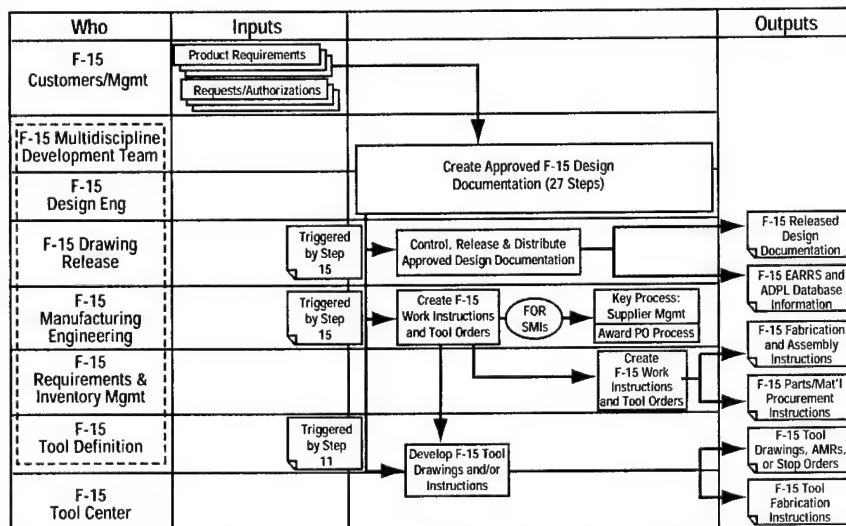


Figure 3-4. Ready-to-Fabricate Development Program

developed to indicate completion of the Ready-to-Fabricate Process. Additionally, the process fosters continuous improvement by including exit criteria at each milestone and requesting suggestions for changes/additions to both exit design criteria and process design guides.

The process also includes metrics to measure product part count reduction, fastener quantity and type reduction, fabrication and assembly tool reduction, and reductions in defects per unit and assembly cycle time. Initial efforts on one major program have lead to fewer parts (122 to 76), fewer fasteners (1068 to 541), reductions of fastener types (55 to 30), fewer tools (108 to 47), lower fabrications costs (41%), and dramatically reduced assembly times (75%).

The process is fully documented and can be moved to other products.

Unigraphics

MDA (St. Louis) extensively uses Unigraphics as its standard CAD/CAM system for creating build-to packages, assemble-to packages, digital mock-up models, tool design, and the manufacture of tools and parts. With more than 40 separate applications, the commercial version of Unigraphics is extensive and also accommodates many special applications written specifically for the McDonnell Douglas Corporation.

Building on input from its users, Unigraphics is currently adding functionality to Unigraphics. MDA (St. Louis) is a beta test site for Version 10 and will implement the solid modeling and parametric design capabilities when fully released. New Unigraphics capabilities include X Windows interface, parametric design, assembly modeling, CAM applications, and performance tuning.

Wind Tunnel Measurement Techniques

The need for improved quality and greater efficiency in wind tunnel test measurement techniques provided the impetus for MDA (St. Louis) to develop three new methods of testing. These improved test methods provide for faster, more accurate measurement of the wind tunnel model's position and pressure points. They also provide for an automated strain gage balance calibration system.

The model position measurement system utilizes a polarized light sensor mounted into the airframe model that allows for very accurate on-board pitch angle measurement. This simple and ruggedized method precludes the necessity of providing offset weights and corrective mechanical measurements to the mounting fixture utilized to suspend the airframe model in the wind tunnel.

The electronic pressure scanning system consists of several very small and lightweight multichannel electronic pressure transducers, which can provide up to 1,024 chan-

nels of pressure. These pressure channels are connected to a microcomputer. This portable stand-alone system provides for acquisition of multiple data channels with real-time data display capability.

The wind tunnel automatic balance calibration system allows for faster and safer calibration of the strain gage balance which is used to measure the deflection loading of the airframe models. The strain gage balance is attached to the suspension arm that supports the airframe model during a wind tunnel test. The calibration of the balance is now accomplished with an automated fixture that provides the proper application of calibration loads and electronic locking. The loading of the strain gage balance is performed by a hydraulic cylinder in a computer controlled fixture. This allows the calibration of six component balances over multiple load ranges and allows the calibration of balances with varying diameters. The fixture eliminates the need for the manual application of heavy weights and for manual leveling. Calibration time is reduced and quick calibration comparisons can be made via the test processing software.

Production/Facilities

Advanced Trim and Drill Cell - Composites

Implementation of the MDA's (St. Louis) large, flexible Trim System that combines an Abrasive Water Jet System and High Speed Spindle Technology will be completed by July 1995. This DNC system will increase trim edge quality, reduce manpower, and reduce perishable tool usagewhile providing a capability for large composite and complex contour parts. All trimmed parts will only require one set-up.

The Advanced Trim and Drill Cell is a 13-axis, fixed-bed, gantry-type machine capable of trimming with either abrasive water or with a traditional high-speed spindle. This machine is designed to trim flat and compound curvature composite structures. The work envelope is 12 feet (y) by 40 feet (x) by (2) 42-inch z's, where each z axis uses individual rotary axes. An automatic carousel-type tool changer allows the router section a smooth transition to and from required cutters. The Abrasive Water Jet Process uses high pressure water, up to 60,000 psi, and garnet abrasive to form a slurry capable of trimming composite and titanium structures.

Additional capabilities included in this system are drilling, countersinking, reaming, seal groove cutting, chamfering, and core carving. The system utilizes three closed circuit color cameras to observe the process, a waste removal system that removes solid particles from the water jet waste effluent, a 10-station carousel tool changer for automatic tool exchange, probing capabilities for accumulation of SPC data, and a redundant water pump capable of being switched on the fly, limiting system downtime.

Part location is accomplished through the use of vacuum cups and surface hole patterns located directly in the holding fixtures. A dry vacuum system is installed to reduce airborne composite dust.

Early process verification data has shown significant cycle time reduction in both set-up and actual trim, with set-ups being reduced from eight to one over hand trim methods. Increased quality is expected through the utilization of programmable feeds and speeds along with reduced trim tool damage normally encountered in hand routing. With a total investment of \$2,425,517, including equipment and facility costs, the five-year annual savings is projected to be \$990,872.

Airbag Shimming on the F/A-18E/F Wing

The F/A-18 E/F requires 100% liquid shimming between composite and mating structures. MDA (St. Louis) applies an airbag shimming method which uses a large, low pressure, pneumatic tool to apply constant, uniform pressure over large, irregularly shaped surfaces while the liquid shim material cures. Previously, MDA (St. Louis) performed liquid shimming by using wedgeloks which produced localized pressure on the skin, resulting in undesired thickness variations in the liquid shim. The new method uses an airbag shimming tool, which has C-channels containing airbag inserts, and is attached to the assembly jig. When the airbag is inflated, it produces even pressure against the composite skin.

With this airbag shimming method, two holes are drilled prior to liquid shimming to maintain the skin/substructure relationship. The gap check is performed by attaching the airbag tooling and pressurizing the airbag. While the liquid shim is curing, the pressure on the composite skin is uniform and constant, so the quality of the liquid shim thickness is improved over that obtained through the wedgelok method. After the liquid shim is applied to the opposite surface, the wing is moved to the Automated Drilling System for final drillout. This method eliminates the need for installing large numbers of cumbersome wedgeloks.

Fiber Placement

MDA (St. Louis) uses a fiber placement process to fabricate large and complex parts that are difficult to produce by conventional methods, and which reduces the material waste from hand layup. To support this fiber placement technology, MDA (St. Louis) plans to have its fiber placement machine (constructed by Ingersoll Milling Company in conjunction with Hercules) on-line in August 1995. Fiber placement technology will be inserted into a production setting with the F/A-18 E/F. Another potential program is the C-17.

The CNC, seven-axis machine has a work envelope of 20 feet in diameter and 37 feet in length and is capable of supporting a combined part and tool weight of 80,000 pounds. The machine has a 32 tow head which utilizes a 0.182-inch width tow (5.82 inches band width).

Material acceptance tests have been performed satisfactorily at Ingersoll, and more are being conducted at MDA (St. Louis). Different ways of using the machine are also being investigated. Fiber placement work cells and applications are being configured to produce affordable composite structures. Continuous improvements are planned with inspection methods, material handling, and machine reliability.

FLASHJET™ Coating Removal Process

MDA (St. Louis) recently obtained a patent for an automated robotic technology identified as the FLASHJET™ Coating Removal process. This FLASHJET™ process uses a powerful pulse (15-23J/sqcm) of high intensity light to destroy the molecular structure of surface coatings. Simultaneously, a low pressure stream of dry ice particles cools the surface and sweeps away the ablated coating residue. This process allows removal of any coating from any surface with extraordinary precision, leaving no damage to substrates, no media intrusion, no corrosion potential, and an absolute minimum waste stream.

The system contains a color sensor subsystem which controls lamp power during stripping to prevent substrate damage. This allows the system to strip multiple layers of paint from the substrate while leaving the primer intact, ready to be repainted immediately. Additionally, FLASHJET™ was designed to address environmental impacts and worker safety/health issues. It filters hazardous solids from the waste stream, releasing an exhaust with only 10 ppm light hydrocarbons. Any removed waste is captured in disposable filter bags so operators are not exposed to dangerous by-products. Other benefits include worker acceptance, improved productivity, reduction of hazardous waste, environmental compliance, and reduced operating costs. For example, the cost of paint removal with the FLASHJET™ is approximately \$3.74 per square foot, depending on geographic location. With chemicals the cost is \$33.61 per square foot and with plastic media blast it is \$15.40 per square foot.

MDA (St. Louis) has the first production model of this machine and is currently going through a series of mechanical validation tests for many different material types and manufacturing processes. There is no limit to the number of times the FLASHJET™ process can be applied to aircraft surfaces. The system has been fully qualified by the FAA for paint stripping applications on all of McDonnell Douglas aircraft structures and all Air Force F-15E program

parts. MDA (St. Louis) is working on approval of this process for Airbus Industries, Boeing Aircraft, and Navy and Army products.

Future plans include the design and manufacture of a second generation FLASHJET™ System for marketing by MDA (St. Louis). There is significant interest in this product from both U.S. repair facilities and foreign governments.

Ion Vapor Deposition

MDA (St. Louis) has eliminated many cadmium plating and zinc coating processes and replaced them with the Ion Vapor Deposition (IVD) process. The IVD process deposits a uniform, dense coating of pure aluminum on steel, titanium, and aluminum alloy parts and provides outstanding corrosion protection. This process eliminates many of the environmental problems associated with vacuum-deposited cadmium, electroplated cadmium, and diffused nickel-cadmium. IVD aluminum is a ductile coating and will not affect the fatigue life of high-strength aluminum alloys. Figure 3-5 illustrates the basic parts of a IVD Rack Coater, including a steel vacuum chamber, pumping system, evaporation source, high voltage power supply, and internal racking system.

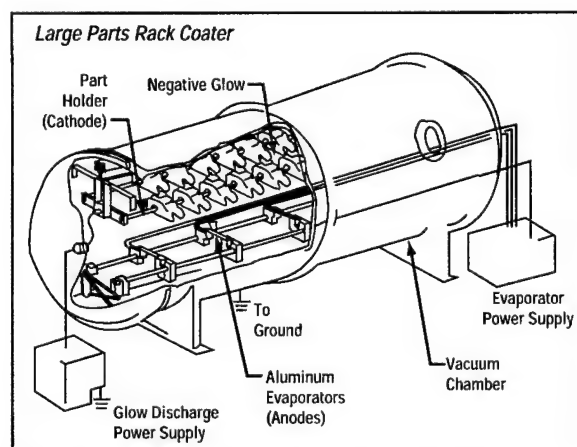


Figure 3-5. Ionic Vapor Deposition Rack Coater

After the parts to be coated have been mounted onto racks and loaded into the chamber, the vacuum chamber is pumped down to approximately 10^{-4} torr, backfilled with an inert gas, and a glow cleaning process commences. Following the cleaning process, commercially available pure aluminum wire is continuously fed into the chamber and evaporated. A portion of the aluminum is ionized and is attracted to the negatively charged part. This results in a dense, thick, adherent coating of aluminum.

This process has proven to be quite effective when used in direct contact with titanium where cadmium is prohibited, on steel parts that will be in direct contact with fuel, and on dissimilar metals that would normally create corrosion problems.

Large Order Assembly Planning System

MDA (St. Louis) has developed a computerized planning process – or Large Order Assembly Planning System (LOAPS) – to enhance the assembly of large order items. It uses a relational database on an IBM mainframe computer to provide step-by-step assembly instructions to shop personnel. Major assembly work plans are developed by Manufacturing Engineering using input from various planning sources. LOAPS serves as a liaison for the Assembly Shop, Production Control, Tooling, Design Engineering, Production Methods Engineering, Quality Assurance, and Scheduling departments.

System features include on-line editing to provide current production changes, component/tool lists, security protection, highlighted text for latest revisions, quality assurance requirements, and the capability of on-line review by all involved parties. This information is available to shop personnel in book form consisting of drawings, assembly instructions, and visual aids as digitized photographs.

LOAPS has become a vital part of the major assembly planning process storing more than 98% of the assembly instructions. When the project is completed, the information is archived to provide historical data and a record of any problems encountered in the assembly process.

Laser-Guided Ply Locating System

MDA (St. Louis) has installed a Laser Guided Ply Locating system (manufactured by General Scanning) for composite part manufacturing. The system uses lasers to project the outline of the individual plies and cut-outs directly onto a hard tooling locator tool.

The traditional method for locating composite plies consisted of using either a Mylar locating template or a hard tooling locator. The Mylar was difficult to use because the mechanic was required to work under the Mylar, making it more difficult to detect foreign material. Hard tooling locators are expensive and cumbersome and to locate plies, multiple locators are frequently required to accommodate all the plies. The mechanic must manually scale off a known ply to determine the location of an unmarked ply. The Laser Guided Ply Locating system eliminates these locators.

The system consists of two machine controllers, one factory workstation, two Class 3A laser projectors, and a frame support for the projectors. Each projector has a work

area of 10 feet by 10 feet. The projectors can be used independently to concurrently display different parts. The projectors can also be used together, each displaying half the part, for a total work area of 10 feet by 20 feet. The system can be programmed off-line or manually (teach mode). Accuracy is ± 0.015 -inch from any point in the projection field to any other point in the field.

One Laser Guide System is installed and program development is in progress. The second machine will be operational in May 1995. Training and acceptance testing will be completed by the end of June 1995. The total cost to implement these two machines was \$270,580. The projected savings over five years is \$560K.

Laser Tracking System

MDA (St. Louis) purchased a three-dimensional laser tracking system from Leica in 1994 as a state-of-the-art portable inspection system that can be used in various locations throughout the plant.

The Leica system includes a tracker head assembly and retro reflector, networked PC, and a controller consisting of a power supply, motor amplifiers, encoders and interferometer electronics. The tracker can measure a surface from varying distances and allows substantial flexibility with large irregular shapes. The machine can be used as a test bed for final assembly and machine shop applications. It can also be used to test a machining program without cutting material, to certify machine alignments, map contour surfaces and mold lines, and to reverse engineer surfaces. This equipment can also be used in place of a CMM on large parts that are too cumbersome or too complex to remove from a machine for inspection.

MDA (St. Louis) maintains that the laser tracking system can do the work of a four-head theodolite system faster and cheaper, and can work to closer tolerances. Projected annual savings of using this system over conventional tooling bars and optics is approximately \$940,862.

Machining Center Feature-Based Process Coding Methodology

MDA (St. Louis) extends group technology part classification efforts with the Machining Center Feature-Based Process Coding Methodology to include process information. The objective of this program is to provide feedback to designers to improve detailed part design.

The methodology is based on an eight alpha/numeric character process code that is critical to communicating the manufacturing capability for a given part to MDA (St. Louis) customers and engineering personnel. A process capability feature model is conveyed to engineering by identifying design form features such as slot, fillet, stiff-

ener, and hole on a part, and attaching manufacturing information to that form feature. The process code identifies the center that will fabricate the part, the specific machine, tolerance range, basic process, material identifier, tool application, and associated design form feature.

The process code provides clear language, exploits the advantages of feature-based design, and assigns processes by similarity of part fabrication including process capability machine selector. The process code has been incorporated in a variety of in-house process control efforts such as the statistical process control system.

Metronor Photogrammetry

MDA (St. Louis) is piloting the implementation of a Metronor Photogrammetry System, a video-camera based, computer-coordinated measurement tool that provides three-dimensional x, y, and z points. Photogrammetry data is verified automatically using Unigraphics models.

The system was purchased from Metronor AS of Norway and consists of two Kodak cameras, an IBM notebook computer, HP DeskJet printer, Sun workstation, and two light pens.

Through use of the Metronor Photogrammetry System, MDA (St. Louis) is striving to eliminate the use of wet film cameras where film development does not allow for real time information gathering. The new photogrammetry system on-line data storage capability will also replace large, hard copy quality assurance data sets.

Using this system, Unigraphics models will be downloaded to the shop floor, allowing real time measurements and analysis to be made. This real time processing will improve the cycle time and help avoid inspection escapes. System accuracy is a function of video camera spacing on the floor. When inspecting individual parts, accuracy has been demonstrated that is equal to the CMM capability (plus or minus 0.001). The new photogrammetry system will be useful in meeting Quality Assurance inspection requirements such as tooling accuracy verification and validation, and aircraft surface waviness measurement.

Cost savings data has been estimated for the Metronor Photogrammetry System. The current cost per detail inspected is \$368, compared to \$14.50 with the new system. Cycle time is also reduced from 12.7 man hours per detail inspected to 0.5 with the new system. With an estimated 625 details inspected per year, total cost savings of \$220,937 and total cycle time reduction of 7,625 man hours are projected.

The system is in pilot program testing. MDA (St. Louis) is planning a future quality assurance measurement strategy using the Metronor Photogrammetry System in conjunction with other advanced equipment such as the Laser Tracking Measurement System, portable CMMs, and Theodolite

Measurement Systems. These devices will be electronic, computerized measurement systems which use Unigraphics models on a real time, interactive basis. This will eliminate the need for previously generated inspection points and manual evaluation of measured results. Future systems will also have a voice-activated interaction capability.

Paperless Assembly Data Delivery System

PADDs provides MDA (St. Louis) with an efficient, integrated, electronic system for delivering, retrieving, processing, and storing assembly build-data and work instructions. The system runs on an IBM mainframe system using MDA (St. Louis) developed software and X-Terminals.

PADDs allows quick electronic access to the work instructions, drawings, specifications, notes, and visual aids associated with an assembly order. It includes electronic call boards to reduce travel and queue times for organizations such as quality assurance and production control. The system accommodates real time postings which provide an on-line, current WIP status, and allows for accurate selection of change affectivities. The system provides increased visibility of the assembly process for a more efficient assignment of open work and efficient part removal documentation and tracking. The system can enforce business rules, such as inspection/operator certifications and qualifications, and the verification of the completion of operations. In addition, the system is designed with the flexibility to support future needs such as data collection, work scheduling, and advanced work instruction technologies.

Early implementation on a major aircraft program have been very favorable. An independent cost/benefit analysis is scheduled for later in 1995, and – provided the cost savings are as expected – the system will then be fully implemented.

Predictive/Proactive Maintenance Management

MDA (St. Louis) addressed the need for effective maintenance scheduling and machine monitoring that is critical to sustaining its high quality and complex machining capability. This was accomplished by developing a maintenance concept based on identification of critical equipment that comprise a Critical Path Equipment list, and by developing metrics to quantify the service quality of the Critical Path Equipment. These metrics are focused on the MTBF and breakdown response/repair cycle times. This effort will ensure that MDA (St. Louis) continues to have a high speed machining technology that provides alternative manufacturing processes accommodating new design alternatives for part designs.

This maintenance management concept employs a customized version of a commercial software package by the Electronic Data System Corporation called PERMAC. Using this software package (including its integration to other software packages to support the maintenance concept), Critical Path Equipment on the shop floor is tracked to ensure timely maintenance procedures for those pieces of equipment. The maintenance schedule is coordinated with the fabrication schedule to provide a harmonious transition between fabrication and required maintenance through PERMAC Computerized Maintenance Management. The Critical Path Equipment listing concept identifies critical machines that impact the fabrication process throughput for the machine center. This consequently raises the machine's visibility to the shop floor user and management. Tracking of individual equipment is monitored by the Property Management System which is integrated with PERMAC.

With these capabilities integrated, PERMAC manages work order scheduled maintenance and installation/construction tasks. PERMAC can track individual property (equipment) numbers, labor cost, maintenance cycle time, and work order history.

With the PERMAC implementation, the maintenance concept has developed into a more robust capability of predictive/proactive maintenance for the shop floor with advanced diagnostics and testing tools. Critical Path Equipment is periodically tested for positioning to ensure proper machine alignment for operation. Integration of a vibration analysis tool estimates the requirement for maintenance and re-calibrating rotating equipment. Equipment sensors and on-line data acquisition will help assist in daily data gathering to depict the status of the system stored by PERMAC. With the historical data, predictive maintenance can then be carried out.

A major benefit achieved through this maintenance concept is increased throughput, or minimal mean time between failure for Critical Path Equipment. Scheduled repair time accounts for only a 4% loss of machine operation time since maintenance cycle times have been reduced. Also, this maintenance concept impacts the spare part procurement lead time estimates since minimal breakdown requires fewer replacement parts and consequently reduces inventory.

Production Control Super Crib

MDA (St. Louis) installed a Noran bar coding system utilizing radio frequency data transmission within its warehouse facility in 1994 to eliminate manual recordkeeping methods and inconsistent material distribution techniques.

MDA's (St. Louis) goal for implementation of this new technology will be to establish consolidation of its Materials

Management Department into one enterprise group responsible for all inventory control functions across the entire company. This will improve inventory accuracy and provide better utilization of manpower in the material control process. Additionally, this process will include the establishment of an inventory shortage reporting process and provide an accurate account of inventory for distributing all internal and external work orders.

The automation of MDA's (St. Louis) inventory tracking and control system and the utilization of system "pull" manufacturing methods will enable MDA (St. Louis) to accomplish just-in-time delivery of kitted parts to the shop floor. The use of this new production control system will provide reduced inventory levels, improved return on net assets, increased turns of tangible inventory, improved productivity, increased part accountability, and improved performance measurement reporting.

Source Selection Process

MDA (St. Louis) developed a source selection manual that addresses the best value instead of low bid in procuring contractor furnished equipment, major subcontract items, and support equipment, systems, and trainers.

The manual addresses two approaches used in the source selection process – the traditional method and the Collaborative Buy-to-Package Development method. The traditional method involves a package development by MDA (St. Louis), submission to bidders for price proposals, evaluation, and award to the bidder offering the best value product or service. With the second method, teams from MDA (St. Louis) and each supplier collaborate to develop a Buy-to-Package, and it is then priced. Evaluation of suppliers, their design approaches, and prices are ongoing throughout the collaboration. This method gives suppliers a chance to make recommendations to help allow them to offer their best value.

Source selection teams include representatives from several different disciplines. Each team member evaluates and scores those portions of the proposal for which they have expertise. Points are allocated at a rate of 30% each for technical, management, and supplier certification (including prior performance) and price. There is a 10% allocation allowed for team (program management) discretion. Maximum point allocation for past performance is permitted for suppliers who have been certified through MDA's (St. Louis) preferred supplier certification process.

Supplier Base Management Process

The Supplier Base Management System at MDA (St. Louis) helps reduce the total number of suppliers without

affecting the quality of products or services received. Each supplier is assigned to one of five specific commodity groups – avionics, electro/hydro/mechanical, major subcontract, production material, and support equipment. The system is designed to eliminate poorly performing suppliers while encouraging others to participate in the Preferred Supplier Certification process.

Two general operating procedures detail the regulations that govern the Supplier Base Management System. They address such areas as entry of a new supplier into the MDA (St. Louis) base, and transfer of suppliers between commodity groups and the Preferred Supplier Certification process, including upgrading and downgrading. The process provides a method to achieve supply base optimization by commodity, establish disciplined entry, initiate maintenance and disengagement procedures for suppliers, and promote utilization of certified suppliers throughout MDA (St. Louis).

Since full-scale implementation of Preferred Supplier Certification and identification of the supplier base in 1990, the total number of MDA (St. Louis) suppliers has dropped from 7271 to 2477. Concurrently, the number of certified suppliers has grown from 3 to 454.

Logistics/Management

CAD/CAM Training

MDA (St. Louis) CAD/CAM users are transitioning from the use of EDS' Unigraphics Version 9 to Version 10. While this transition represents a significant upgrade from wireframe to solid modeling capability as well as many other features, it also necessitates the retraining of all current users since Version 10 has a new user interface. Retraining users will be accomplished using the Computer-Assisted Self Teach On-Line Library training program instead of the traditional method of instructor-led classes.

Computer-Assisted Self Teach is an on-line, interactive, self-paced training tool modeled after a traditional instructor-led course and is regularly updated to remain consistent with the current Unigraphics release. Current tutorials include Parametric Modeling Fundamentals and Version 10 Drafting Fundamentals as well as a new Manufacturing Transition course. Many benefits of Computer-Assisted Self Teach are now being realized, such as availability and convenience to users at their workstations, and the ability to accommodate a high volume of users. Major cost savings are also expected to occur through significant reductions in courseware development – estimated at 50% reduction; courseware maintenance – 70% reduction; instructor pay – 40% reduction; and reproduction of training manuals – 60% reduction.

The Creative Edge

MDA (St. Louis) has created a pilot program to encourage and recognize employee involvement as part of the continuous improvement process. This program—instituted with the help of a small firm in the St. Louis area—includes monetary incentives for the employees as well as their immediate supervisor (or manager). The program is new; however, the recent performance from the pilot study indicated a \$7.3M documented savings coming from the implementation of 120 ideas. These ideas resulted from the efforts of 1194 employees who shared nearly \$300K in compensation.

Enterprise Quality Improvement Board

The Enterprise Quality Improvement Board (EQIB) at MDA (St. Louis) ensures consistency of enterprise quality improvements by identifying these initiatives and monitoring them through completion. An enterprise includes all corporate functions within an operating unit's sphere and typically encompasses all activities in one geographical area—such as MDA (St. Louis) facilities. The EQIB is the operational management level quality review group within MDA (St. Louis) and is comprised of program managers from all programs or business units.

The EQIB communicates and integrates performance metrics, ensures consistency in quality improvement, identifies opportunities for quality improvement, sets priorities for identification of enterprise quality efforts, selects areas for measurement and performance targets, analyzes enterprise-wide quality performance metrics, resolves enterprise-wide issues that are elevated from lower level boards, reduces defects through support of the corrective action process, and communicates quality values across all functions within MDA (St. Louis).

Quality Improvement Boards report to the EQIB (Figure 3-6) and are tasked to ensure that an effective corrective action system is functioning through all programs, product centers, and suppliers. Every program or

business unit has a Quality Improvement Board, and each Quality Improvement Board has in its membership the program manager, deputy program manager, quality manager, other MDA (St. Louis) members, and a representative from the government. This effort improves government and industry communications, dialogue, and performance.

The EQIB has overseen the implementation of the Problem Identification, Escalation, and Resolution process; improving (reducing) the cost of quality standards; setting standards for corrective action cycle time; and providing consistency of Quality Improvement Board approaches through rotating monthly meetings.

This avenue for retaining and maintaining quality has the potential to be effective, and while some form of this effort has been in place at MDA for years, this particular structure is still in its early phases and demonstrating strong signs of success.

Ethics Refresher Process

MDA (St. Louis) conducts a continuing ethics awareness program to reaffirm the company's adherence to ethical principles of behavior that produce high quality products and loyal employees, customers, suppliers, and investors. It is led by supervisors for their employees with a target goal of 100% participation by the end of 1995. This refresher

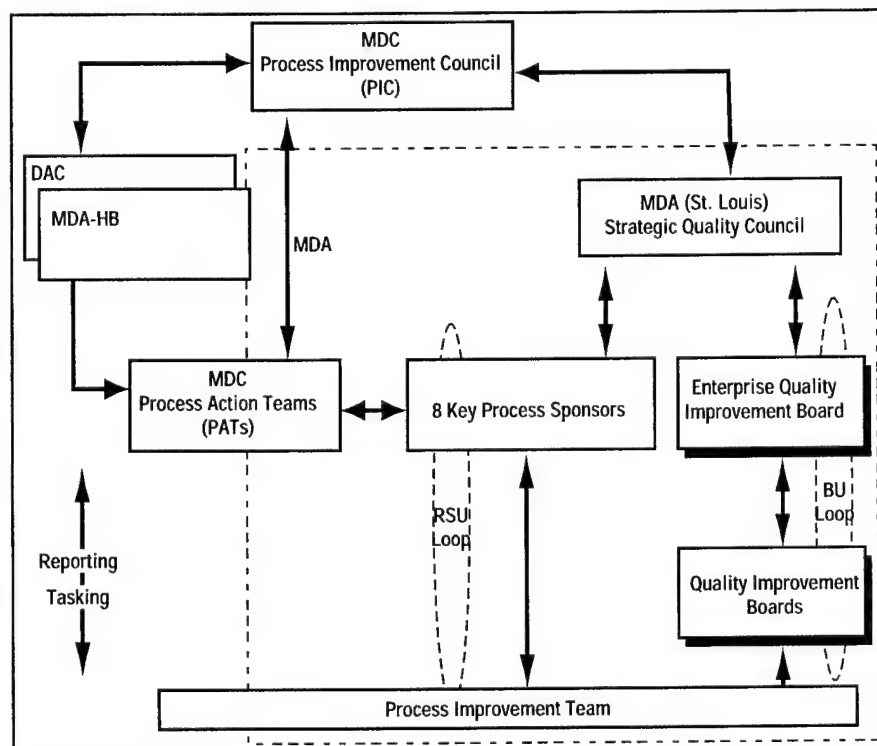


Figure 3-6. EQIB Relationship to Other Boards/Councils

program consists of a 1995 Refresher Video which presents the Code of Ethics and Ethical Decision Making Model along with practical situations and class discussions, and a Pocket Card explaining the Code of Ethics and contacts and phone numbers if help is needed.

This Ethics Refresher is designed to heighten every employee's awareness of ethics as an integral part of their everyday lives and jobs. It shows that high ethical standards depend on being knowledgeable, setting high expectations, and communicating.

Field Visits/Site Surveys

MDA (St. Louis) conducts field visits/site surveys for early assessment of customer locations and facilities for the placement of weapon systems. These surveys are also conducted to determine customer needs and to assess field performance after the weapon system is fielded. The assessment of these visits is included in the LSA documentation.

The survey process is structured using a systems engineering approach. Contract data requirements form the basis for system inputs, and the transformation is made through LSA program planning and management. Mission and support system definition is the result of this process.

Data obtained from the visits is used in life cycle cost analysis; design-to-cost efforts; reliability, maintainability, and availability analysis; and the development of training requirements. In addition, all weapon system requirements determined as a result of site visits are tied into the overall program schedule to ensure all requirements are accounted for.

MDA (St. Louis) has participated in several benchmarking efforts including the Price Waterhouse 2000 Project, the Aerospace Industries Association LSA Benchmark, and internal Total Quality Management System evaluations. Applications of this site survey process – along with the use of skilled logisticians – has earned MDA (St. Louis) high marks in the LSA process.

Another feature of MDA's (St. Louis) LSA success is attributed to the development and use of Customer Contact Plans. These plans identify annually scheduled visits and locations. This permits a free flow of communication prior to field visits and allows each site time to prepare both the site for the visit, as well as documentation in relationship to the needs and requirements. All contacts with the customer are summarized in a dedicated database for traceability and follow-on efforts.

The success of MDA's (St. Louis) field visits is measured through a number of corporate metrics which include quality, delivery schedule, and customer response time. Results include a 75% to 95% increase in quality and scheduled deliveries. MDA (St. Louis) has improved on its response time goal of 24 hours, with an average of only two hours.

Over the past three years, MDA (St. Louis) has made substantial changes in its LSA process in skill requirements and the automation environment.

Field Service Engineer's Manual

In 1987, MDA (St. Louis) developed a Field Service Engineer (FSE) Manual for ready reference use by 100 field service representatives located at 64 sites throughout the world.

The FSEs previously had no single guidance document for use at their remote assignments. The comprehensive manual, available on-line in WordPerfect format for the past three years, now provides the working level detail necessary for the FSE's successful conduct of daily support operations throughout the world. The manual design addresses support for the customer in the field as well as support for the MDA corporation.

The manual is divided into seven sections to include:

- General - Corporate organization, philosophy, culture
- FSE Duties and Responsibilities - Customer service, image, professionalism, conduct
- Domestic Travel - detailed travel policies, e.g., rental car, expense reports
- Foreign Travel - Covers policies outside the United States, e.g., currency, emergencies.
- Communication - Conduit of information to the customer and MDA (St. Louis); includes report types and formats
- Security - Considers sensitive information and personal security and restrictions
- Index - Information cross-reference.

The manual is continuously updated with periodic changes to amend local and foreign policies, and a 24-hour service is available for emergency problems. This FSE's manual provides MDA (St. Louis) personnel a comprehensive reference source for executing daily service operations in the field.

Instructional Design Consulting Manual

MDA's (St. Louis) Employee and Organizational Development program supports the organization's growing need to develop training outside the range of management and professional development courses. Using an industry-standard process integrated with the consulting process, internal Instructional Design Consultants help customers generate specific training programs and materials to be used with their work groups. An Instructional Design Training Guide has been published describing the consulting process to assist customers in developing training programs. The guide can also be used for designing "train-the-trainer" workshops for potential course developers and trainers.

The Instructional Design consulting process consists of interactive steps such as meeting with the customer, analyzing training needs, designing training programs, developing training programs, implementing training programs, evaluating training effectiveness, and determining the next actions. Major benefits of this structured approach to assisting users with their training needs are the ability to meet the organization's specific training requirements in a professional, focused way, the capability to measure training efficacy, and maximizing the resources of training professionals.

Methodology for Process Improvement Monitoring

MDA's (St. Louis) HR department developed a quick and manageable methodology to review and monitor process improvements within the HR organization. This methodology was required by management to monitor process improvement efforts where processes and their ownership were not defined and information was needed to assist in the decision-making process at the executive level.

The HR and Services Organization General Services Process Summary Form is a one-page form used for all documented processes within the General Services organization. Senior management and process owners use the form to monitor documented processes, establish metrics, and develop process improvement plans with specific action items. The HR Services Process and Summary Form has been used throughout Level 1 (executive level) and Level 2 (mid-management) processes. Level 3 operational processes are currently being documented and process forms implemented.

The key to using the forms is first to establish process documentation requirements. Training is a critical factor in this process documentation effort, and each process owner receives eight hours of training before documenting individual processes. Process owners must quantify the elements that comprise their processes and identify/implement significant metrics.

One benefit MDA has realized by applying this methodology is the realization that "What you measure, you pay attention to and what you pay attention to, you improve." Process owners are improving processes; there is an increased awareness and visibility of HR processes and improvements; and management has more accurate data on which to base its decisions.

New Business Acquisition Process

MDA (St. Louis) combined best practices from MDC, benchmarked against many leading companies, and secured the services of an outside consultant to develop a



Figure 3-7. Steps in the New Business Acquisition

carefully considered and structured approach toward acquiring new business. Figure 3-7 illustrates these essential steps in the process, the most important of which is never omitting a step. MDA's (St. Louis) structured approach has led to significant improvement in securing competitive contracts.

MDA (St. Louis) determined during the development of this process that many of the steps involved in acquiring new business were similar or identical to the steps in the process of assuring customer satisfaction with existing customers. These six subprocesses include to: identify customers, and develop and deploy a contact plan; improve customer relations; understand customer requirements and expectations; capture and respond to customer inputs; measure, improve, and report customer satisfaction; and improve the customer satisfaction process.

To ensure continuous improvement of these processes, MDA (St. Louis) has established a customer satisfaction quality improvement core team and subteams for eight customer areas.

Both areas of business development are now under the same corporate representative, and personnel work and train in a mutually beneficial effort. Although this organizational structure is new, MDA (St. Louis) speculates that each process will enhance the other.

On-Line Spares Acquisition

MDA (St. Louis) has developed an on-line spare parts requisitioning capability that enables customers to access and order spare parts automatically through the use of Electronic Data Interchange. Initial operations address Spare Part Order Administration and EDI transactions for Request for Quote (840) and Response (843) and are currently operational with the Navy's Aviation Supply

Office. Although the present process for on-line requisitioning is a mixture of both manual and automated methods, these improvements have greatly reduced requisition time from several months to several days. MDA's (St. Louis) benchmarking results in this area indicate that it can expect further improvements and reach a cycle time of about two hours by fully automating the process.

Recognition Programs Structure

MDA (St. Louis) instituted a structured awards program to enhance morale and productivity in the work force. This program was initiated in response to a Survey of Organizations conducted in late 1991 that noted employees desired improved methods for recognizing and rewarding good performance. A recognition program was developed encompassing the following four categories.

- Quality Awards - presented by the organization for performance-related accomplishments
- Customer Driven Recognition - presented by a satisfied customer; internal or external to MDA (St. Louis)
- Service and Commitment - recognizes years of service or rewards perfect attendance
- Organizational Achievement - includes community activity

MDA (St. Louis) developed a handbook that defines the new recognition program and provides a convenient how-to manual for nominating deserving teams or individuals. The manual and process have effectively increased recognition of the work force as evidenced by the eight-fold increase in recognition from 1991 to 1994 (Figure 3-8).

Retrofit Kit Proofing Support

MDA (St. Louis) has instituted retrofit proofing to comply with an Air Force requirement to ensure that component parts, drawings, personnel skills, and procedures are available to complete the retrofit. An Automated Retrofit and Kit System used by MDA (St. Louis) tracks the kit movement, kit parts, and overall retrofit schedules. The kit proofing support system notes the manhours expended for kit installation (to apply to subsequent kit installations) and also records disposition of parts removed from the product during the retrofit process. Skill levels needed to install the retrofit are also recorded.

The MDA Retrofit Kit Proofing process effectively minimizes downtime of customer aircraft and optimizes corporate time, schedule, cost, and parts availability.

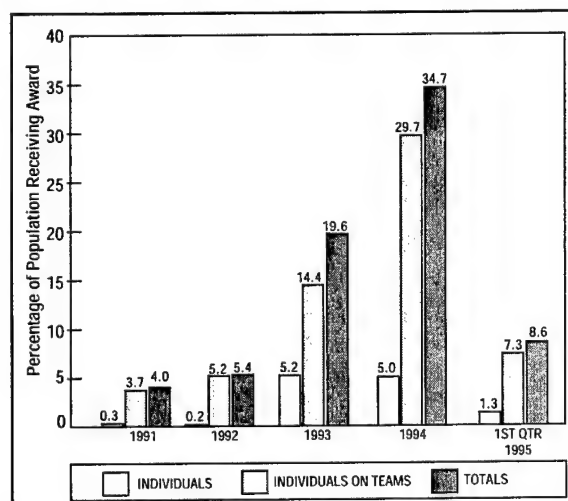


Figure 3-8. MDA (St. Louis) Quality-Related Rewards and Recognition

Appendix A

Table of Acronyms

ACRONYM	DEFINITION
AJA	Assembly Jig Accessory
ADQAS	Advanced Design for Quality Avionics Systems
AMPS	Automated Mass Properties System
AUSS	Automated Ultrasonic Scanning System
BCS	Baseline Comparison System
CALS	Continuous Acquisition and Lifecycle Support
CFD	Computational Fluid Dynamics
CITIS	Contractor Integrated Technical Information Service
CMM	Coordinate Measuring Machine
CR	Computed Radiography
DB	Diffusion Bonding
DFMA	Design for Manufacturing and Assembly
DOD	Department of Defense
DPVA	Digital Photographic Visual Aid
DQAS	Design for Quality Aerospace Systems
EDSS	Engineering Documentation Storage System
E/MTS	Engineering/Manufacturing Tracking System
EQIB	Enterprise Quality Improvement Board
EWO	Electronic Work Order
FEMWTS	Finite Element Model Weight Estimation System
FMEA	Failure Mode and Effects Analysis
FMECA	Failure Mode, Effect, and Criticality Analysis
fpm	Feet Per Minute
FSE	Field Service Engineer
GD&T	Geometric Dimensioning and Tolerancing
HBCU/MI	Historical Black College and Universities and the Minority Institutions
HQA	Hornet Quality Award
HR	Human Resources
HSM	High Speed Machining
IAMP	Integrated Assembly Management Process
I-CASE	Integrated Computer Aided Software Engineering
IEF	Information Engineering Facility
IMICS	Integrated Management Information and Control System
ipm	Inches Per Minute
IPD	Integrated Product Definition
IVD	Ion Vapor Deposition
IWAS	Intelligent Wire Assembly Station

LOAPS	Large Order Assembly Planning System
LRET	Low Rate Expandable Tooling
LSA	Logistics Support Analysis
LSAR	Logistics Support Analysis Record
MDA	McDonnell Douglas Aerospace
MODSDF	Modular Six Degree of Freedom
NDT	Non-destructive Test
PADDs	Paperless Assembly Data Delivery System
PIER	Problem Identification, Escalation and Resolution
QFD	Quality Function Deployment
RCS	Retrofit Configuration System
SQIB	Supplier Quality Improvement Board
SPEARS	Supplier Performance Evaluation and Rating System
SPF	Superplastic Forming
S/SDB	Small and Small Disadvantaged Business
STT	Strategy-to-Technology
TCA	Trichloroethane
TPM	Technical Performance Measurement
TPP	Technical Performance Parameter
VSA	Variation Simulation Analysis

Appendix B

BMP Survey Team

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Appendix C

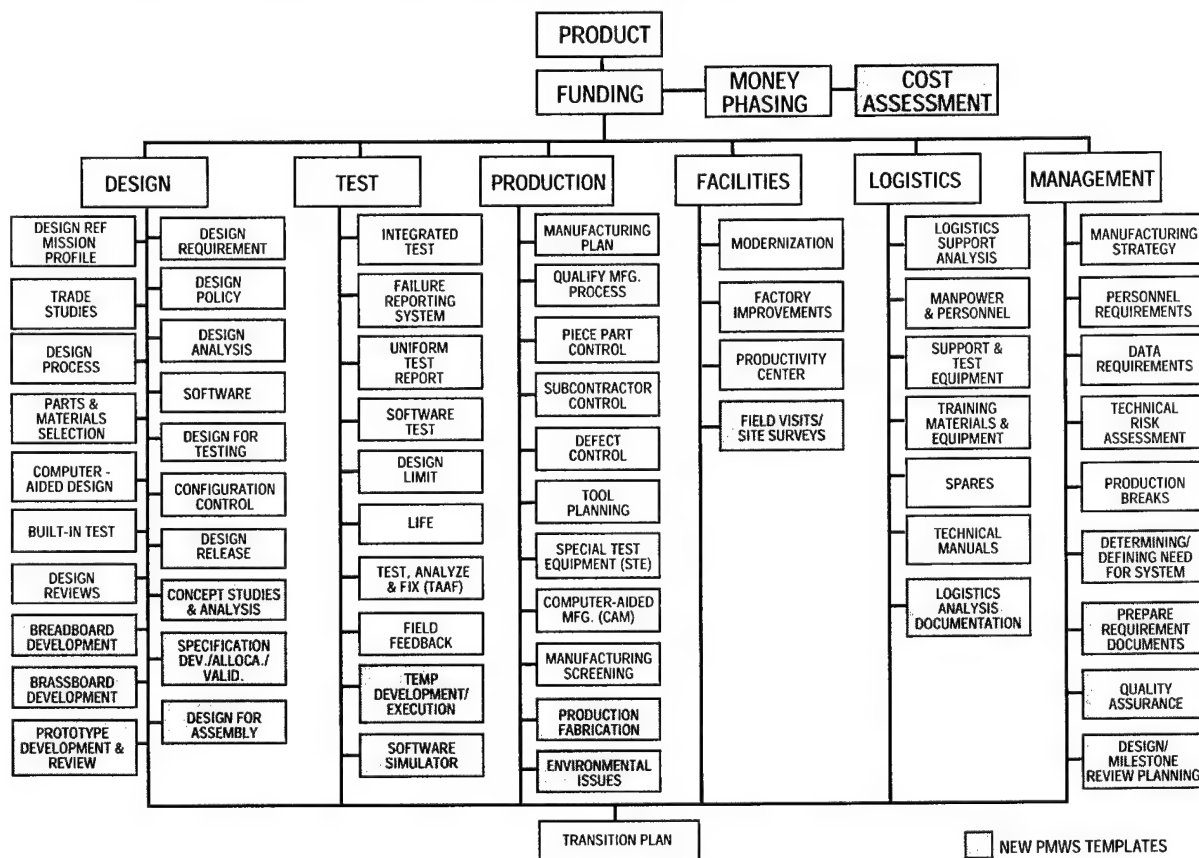
Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, *Transition from Development to Production* document. This publication defines the proper tools—or templates—that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition process by addressing

it as an *industrial* process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

"CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION"



Appendix D

BMPnet and the Program Manager's Workstation

The Program Manager's Workstation (PMWS) is a series of interrelated software environments and knowledge-based packages that provides timely acquisition and engineering information to the user. This Workstation is hosted on the BMPnet that supports communication nationwide to promote technology transfer and continuous improvement. Access to BMPnet is through modem dial-in, free PMWS software, Internet, World Wide Web, or CD-ROM. Besides PMWS, BMPnet features include communication by electronic mail and file transfer; access to Special Interest Groups on more than 75 topics including producibility and Government specifications; information upload and download capability; and the ability to download BMPnet-resident programs.

PMWS includes **KnowHow**, an electronic library of expert technical assistance, including an intelligent search capability that gets the information users need on the screen in less than three minutes; the Technical Risk Identification and Mitigation System (**TRIMS**), a technical risk management system that may be tailored to the user's needs; the BMP database that contains over 2,000 abstracts on documented best practices; and SpecRite, a performance specification development tool.

KnowHow is . . . Knowledge through an automated and intelligent information access system that speeds the search for required information by up to 95%. Typically, the information needed is on the screen in less than three minutes.

KnowHow features include:

- Personalized acquisition planning guidance, both high and low level, as appropriate.
- Information required for user's specific job.
- Special, logic-driven menu that allows fast access to cut research time by up to 95%.
- On-line user's manual and help.
- Application as a learning tool for new acquisition personnel.

TRIMS brings . . . Insight which identifies and ranks those program areas with the highest risk levels.

TRIMS features include:

- Ability to conduct continuous risk assessments to take pre-emptive corrective action.
- Tracking capability for key project documentation from concept through production.
- Identification function of goals, personnel, and future activities in development processes.
- Default values for many categories by program type.
- Ability to tailor all fields to suit individual program requirements.
- Reports generation.

The **BMP Database** provides . . . Information that comes directly from verified practices in industry that government experts search out looking at the best to collect answers and solutions.

BMP Database features include:

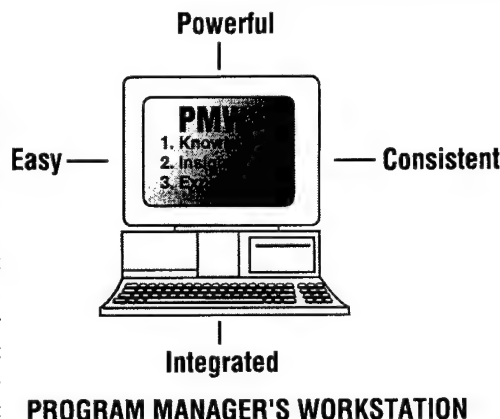
- Information on best practices in manufacturing, design, test, facilities, production, management, and logistics from 80 companies or activities.
- Ability to search for information using a natural language interface.
- Capability to print information to a file, disk or directly to a local printer.

- Phone numbers of points of contact in companies who have been surveyed.

SpecRite can help . . . Develop a performance specification generator based on expert knowledge across the services to guide acquisition personnel in creating specifications for their requirements.

SpecRite features include:

- DOS-base (runs on any PC).
- Organization and structure for the build/ approval process.
- Knowledge-based guidance and assistance.
- Flexible, modular structure.
- Output in MIL-STD 961 format and in WordPerfect 5.1 files.



To access BMPnet, users need a special modem program. This program can be obtained by calling the BMPnet using a VT-100/200 terminal emulation set to 8,N,1. Dial (703) 538-7697 for 2400 baud modems or (703) 7267 for 9600 baud and 14.4kb. When asked for a user profile, type: DOWNPC or DOWNMAC <return> as appropriate. This will automatically start the download of the special modem program. Then call back using this program and access all BMPnet functions. The general user account is:

USER PROFILE: BMPNET

USER ID: BMP

Password: BMPNET

If you want a personal account to receive e-mail, forward your request to Ernie Renner (BMP Program Manager) or Brian Willoughby (BMPnet Program Manager at CSC). If you encounter problems, please call (301) 403-8179.

Appendix E

Best Manufacturing Practices Satellite Centers

There are currently six Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; identify regional experts for inclusion in the BMPnet SIG e-mail; and train regional personnel in the use of BMP resources such as the BMPnet.

The six BMP satellite centers include:

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3301 North Mulford Road
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York, PA

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internnet: <snyderss@mantec.org>

Appendix F

Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Sciences and Technology Program established the following Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and Navy centers and laboratories. These COEs are consortium-structured for industry, academia, and government involvement in developing and implementing technologies. Each COE has a designated point of contact listed below with the individual COE information.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and promote exemplary manufacturing and business practices and to disseminate this information to the U.S. Industrial Base. The BMPCOE was established by the Navy's BMP program, Department of Commerce's National Institute of Standards and Technology, and the University of Maryland at College Park, Maryland. The BMPCOE improves the use of existing technology, promotes the introduction of improved technologies, and provides non-competitive means to address common problems, and has become a significant factor in countering foreign competition.

Point of Contact:

Mr. Ernie Renner

Best Manufacturing Practices Center of Excellence

4321 Hartwick Road

Suite 400

College Park, MD 20740

(301) 403-8100

FAX: (301) 403-8180

ernie@bmpcoe.org

Center of Excellence for Composites Manufacturing Technology

The Center of Excellence for Composites Manufacturing Technology (CECMT) provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors. The CECMT is managed by the GreatLakes Composites Consortium and represents a collaborative effort among industry, academia, and government to develop, evaluate, demonstrate, and test composites manufacturing technologies. The technical work is problem-driven to reflect current and future Navy needs in the composites industrial community.

Point of Contact:

Dr. Roger Fountain

Center of Excellence for Composites Manufacturing Technology

103 Trade Zone Drive

Suite 26C

West Columbia, SC 29170

(803) 822-3705

FAX: (803) 822-3730

frglcc@aol.com

Electronics Manufacturing Productivity Facility

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of industry, university, and government participants, led by the American Competitiveness Institute under a CRADA with the Navy.

Point of Contact:

Mr. Alan Criswell

Electronics Manufacturing Productivity Facility

Plymouth Executive Campus

Bldg 630, Suite 100

630 West Germantown Pike

Plymouth Meeting, PA 19462

(610) 832-8800

FAX: (610) 832-8810

<http://www.engriupui.edu/empf/>

National Center for Excellence in Metalworking Technology

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. The NCEMT, operated by Concurrent Technologies Corporation, helps the Navy and defense contractors improve manufacturing productivity and part reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:

Mr. Richard Henry
National Center for Excellence in Metalworking
Technology
1450 Scalp Avenue
Johnstown, PA 15904-3374
(814) 269-2532
FAX: (814) 269-2799
henry@ctc.com

Navy Joining Center

The Navy Joining Center (NJC) is operated by the Edison Welding Institute and provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues.

Point of Contact:

Mr. David P. Edmonds
Navy Joining Center
1100 Kinnear Road
Columbus, OH 43212-1161
(614) 487-5825
FAX: (614) 486-9528
dave_edmonds@ewi.org

Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality energetics. The focus of the EMTC is on process technology with a goal of reducing manufacturing costs while improving product quality and reliability. The COE also maintains a goal of development and implementation of environmentally benign energetics manufacturing processes.

Point of Contact:

Mr. John Brough
Energetics Manufacturing Technology Center
Indian Head Division
Naval Surface Warfare Center
Indian Head, MD 20640-5035
(301) 743-4417
DSN: 354-4417
FAX: (301) 743-4187
mt@command.nosih.sea06.navy.mil

**Manufacturing Science and Advanced Materials
Processing Institute**

The Manufacturing Science and Advanced Materials Processing Institute (MS&MPI) is comprised of three centers including the National Center for Advanced Drivetrain Technologies (NCADT), The Surface Engineering Manufacturing Technology Center (SEMTC), and the Laser Applications Research Center (LaserARC). These centers are located at The Pennsylvania State University's Applied Research Laboratory. Each center is highlighted below.

Point of Contact for MS&MPI:

Mr. Dennis Herbert
Manufacturing Science and Advanced Materials
Processing Institute
ARL Penn State
P.O. Box 30
State College, PA 11804-0030
(814) 865-8205
FAX: (814) 863-0673
dbh5@psu.edu

• **National Center for Advanced Drivetrain Technologies**

The NCADT supports DOD by strengthening, revitalizing, and enhancing the technological capabilities of the U.S. gear and transmission industry. It provides a site for neutral testing to verify accuracy and performance of gear and transmission components.

Point of Contact for NCADT:

Dr. Suren Rao
National Center for Advanced Drivetrain
Technologies
ARL Penn State
P.O. Box 30
State College, PA 16804-0030
(814) 865-3537
FAX: (814) 863-1183
http://www.arl.psu.edu/drivetrain_center.html/

- **Surface Engineering Manufacturing Technology Center**

The SEMTC enables technology development in surface engineering—the systematic and rational modification of material surfaces to provide desirable material characteristics and performance. This can be implemented for complex optical, electrical, chemical, and mechanical functions or products that affect the cost, operation, maintainability, and reliability of weapon systems.

Point of Contact for SEMTC:
Surface Engineering Manufacturing Technology Center
Dr. Maurice F. Amateau
SEMTC/Surface Engineering Center
P.O. Box 30
State College, PA 16804-0030
(814) 863-4214
FAX: (814) 863-0006
http://www.arl.psu.edu/divisions/arl_org.html

- **Laser Applications Research Center**

The LaserARC is established to expand the technical capabilities of DOD by providing access to high-power industrial lasers for advanced material processing applications. LaserARC offers basic and applied research in laser-material interaction, process development, sensor technologies, and corresponding demonstrations of developed applications.

Point of Contact for LaserARC:
Mr. Paul Denney
Laser Center
ARL Penn State
P.O. Box 30
State College, PA 16804-0030
(814) 865-2934
FAX: (814) 863-1183
http://www.arl.psu.edu/divisions/arl_org.html

Gulf Coast Region Maritime Technology Center

The Gulf Coast Region Maritime Technology Center (GCRMTC) is located at the University of New Orleans and will focus primarily on product developments in support of the U.S. shipbuilding industry. A sister site at Lamar University in Orange, Texas will focus on process improvements.

Point of Contact:
Dr. John Crisp
Gulf Coast Region Maritime Technology Center
University of New Orleans
Room N-212
New Orleans, LA 70148
(504) 286-3871
FAX: (504) 286-3898

APPENDIX G

Completed Surveys

BMP surveys have been conducted at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPnet. Requests for copies of recent survey reports or inquiries regarding the BMPnet may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 400
College Park, MD 20740
Attn: Mr. Ernie Renner, Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
ernie@bmpcoe.org

COMPANIES SURVEYED

Litton
Guidance & Control Systems Division
Woodland Hills, CA
October 1985 and February 1991

Texas Instruments
Defense Systems & Electronics Group
Lewisville, TX
May 1986 and November 1991

Harris Corporation
Government Support Systems Division
Syosset, NY
September 1986

Control Data Corporation
Government Systems Division
(Computing Devices International)
Minneapolis, MN
December 1986 and October 1992

ITT
Avionics Division
Clifton, NJ
September 1987

UNISYS
Computer Systems Division
(Paramax)
St. Paul, MN
November 1987

Honeywell, Incorporated
Undersea Systems Division
(Alliant Tech Systems, Inc.)
Hopkins, MN
January 1986

General Dynamics
Pomona Division
Pomona, CA
August 1986

IBM Corporation
Federal Systems Division
Owego, NY
October 1986

Hughes Aircraft Company
Radar Systems Group
Los Angeles, CA
January 1987

Rockwell International Corporation
Collins Defense Communications
(Rockwell Defense Electronics
Collins Avionics and
Communications Division)
Cedar Rapids, IA
October 1987 and March 1995

Motorola
Government Electronics Group
Scottsdale, AZ
March 1988

General Dynamics
Fort Worth Division
(Lockheed Martin Tactical Aircraft Systems)
Fort Worth, TX
May 1988 and August 1995

Hughes Aircraft Company
Missile Systems Group
Tucson, AZ
August 1988

Litton
Data Systems Division
Van Nuys, CA
October 1988

McDonnell Aircraft Company
(McDonnell Douglas Aerospace (St. Louis))
St. Louis, MO
January 1989 and May 1995

Litton
Applied Technology Division
San Jose, CA
April 1989

Standard Industries
LaMirada, CA
June 1989

Teledyne Industries Incorporated
Electronics Division
Newbury Park, CA
July 1989

Lockheed Corporation
Missile Systems Division
Sunnyvale, CA
August 1989

General Electric
Naval & Drive Turbine Systems
Fitchburg, MA
October 1989

TRICOR Systems, Incorporated
Elgin, IL
November 1989

TRW
Military Electronics and Avionics Division
San Diego, CA
March 1990

Texas Instruments
Defense Systems & Electronics Group
Dallas, TX
June 1988

Bell Helicopter
Textron, Inc.
Fort Worth, TX
October 1988

GTE
C³ Systems Sector
Needham Heights, MA
November 1988

Northrop Corporation
Aircraft Division
Hawthorne, CA
March 1989

Litton
Amecom Division
College Park, MD
June 1989

Engineered Circuit Research, Incorporated
Milpitas, CA
July 1989

Lockheed Aeronautical Systems Company
Marietta, GA
August 1989

Westinghouse
Electronic Systems Group
Baltimore, MD
September 1989

Rockwell International Corporation
Autonetics Electronics Systems
Anaheim, CA
November 1989

Hughes Aircraft Company
Ground Systems Group
Fullerton, CA
January 1990

MechTronics of Arizona, Inc.
Phoenix, AZ
April 1990

Boeing Aerospace & Electronics
Corinth, TX
May 1990

Textron Lycoming
Stratford, CT
November 1990

Naval Avionics Center
Indianapolis, IN
June 1991

Kurt Manufacturing Co.
Minneapolis, MN
July 1991

Raytheon Missile Systems Division
Andover, MA
August 1991

Tandem Computers
Cupertino, CA
January 1992

Conax Florida Corporation
St. Petersburg, FL
May 1992

Hewlett-Packard
Palo Alto Fabrication Center
Palo Alto, CA
June 1992

Digital Equipment Company
Enclosures Business
Westfield, MA and
Maynard, MA
August 1992

NASA Marshall Space Flight Center
Huntsville, AL
January 1993

Department of Energy-
Oak Ridge Facilities
Operated by Martin Marietta Energy Systems, Inc.
Oak Ridge, TN
March 1993

Technology Matrix Consortium
Traverse City, MI
August 1990

Norden Systems, Inc.
Norwalk, CT
May 1991

United Electric Controls
Watertown, MA
June 1991

MagneTek Defense Systems
Anaheim, CA
August 1991

AT&T Federal Systems Advanced
Technologies and AT&T Bell Laboratories
Greensboro, NC and Whippany, NJ
September 1991

Charleston Naval Shipyard
Charleston, SC
April 1992

Texas Instruments
Semiconductor Group
Military Products
Midland, TX
June 1992

Watervliet U.S. Army Arsenal
Watervliet, NY
July 1992

Naval Aviation Depot
Naval Air Station
Pensacola, FL
November 1992

Naval Aviation Depot
Naval Air Station
Jacksonville, FL
March 1993

McDonnell Douglas Aerospace
Huntington Beach, CA
April 1993

Crane Division
Naval Surface Warfare Center
Crane, IN and Louisville, KY
May 1993

R. J. Reynolds Tobacco Company
Winston-Salem, NC
July 1993

Hamilton Standard
Electronic Manufacturing Facility
Farmington, CT
October 1993

Harris Semiconductor
Melbourne, FL
January 1994

Naval Undersea Warfare Center
Division Keyport
Keyport, WA
May 1994

Kaiser Electronics
San Jose, CA
July 1994

Stafford County Public Schools
Stafford County, VA
July 1994

Lockheed Martin
Electronics & Missiles
Orlando, FL
April 1995

Philadelphia Naval Shipyard
Philadelphia, PA
June 1993

Crystal Gateway Marriott Hotel
Arlington, VA
August 1993

Alpha Industries, Inc
Methuen, MA
November 1993

United Defense, L.P.
Ground Systems Division
San Jose, CA
March 1994

Mason & Hanger
Silas Mason Co., Inc.
Middletown, IA
July 1994

U.S. Army
Combat Systems Test Activity
Aberdeen, MD
August 1994

Sandia National Laboratories
Albuquerque, NM
January 1995